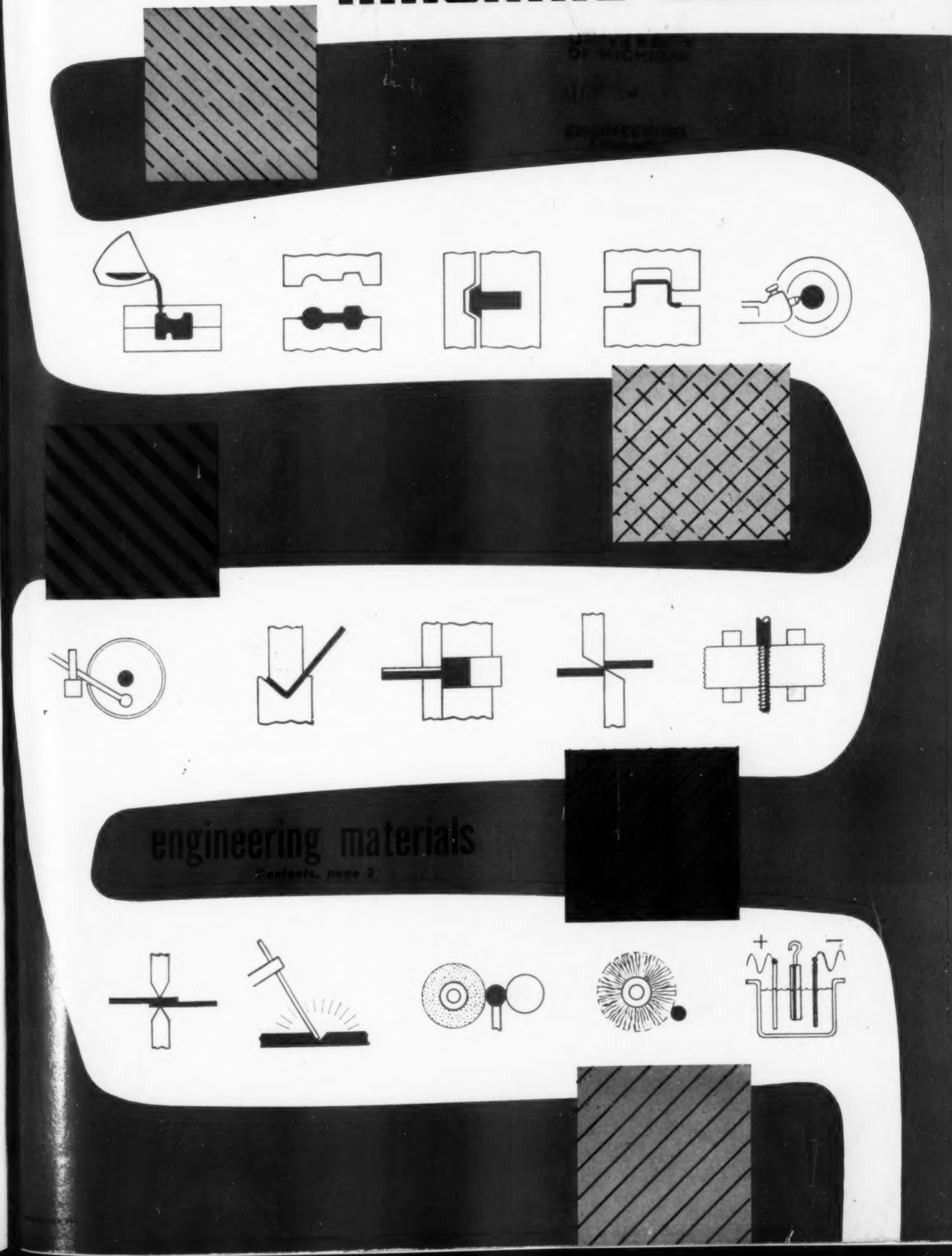
MAY 1955

MACHINE DESIGN



What is your Control Need?

. . . a starter for a fractional hp motor?

This small inexpensive control provides thermal overload protection. . . . Compact construction permits mounting where space is at a premium. Designed for use on ac single-phase power systems . . . up to 230 volts.

. . . a controller for a 2300 to 5000-volt motor?

Here is a control for motors up to 2500 horsepower. All components — contactors, meters, overload relays, auxiliary switches — are selected to meet the particular requirements of your application. Current-limiting fuses give split cycle short circuit protection.

. . . or other applications?

Specific applications, including those between the above-mentioned limits, are made from an extensive line of starters and control components. These standard units are factory assembled in infinite combinations to meet practically any requirement. For help on a particular application, call your Allis-Chalmers representative. His recommendations are backed by Allis-Chalmers engineering departments . . . by experience gained solving thousands of control problems . . . by complete research and testing facilities.

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Milwaukee 1, Wisconsin

THE PROFESSIONAL JOURNAL
FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

MAY 1955
Vol. 27—No. 5

REGULAR DEPARTMENTS

USE POSTAGE-FREE CARDS FOR:

Over the Board

Match Your Impedance

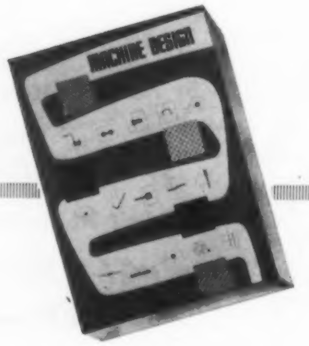
A cute statement of what constitutes a good engineering manager recently came our way from Dean Wooldridge of Ramo-Wooldridge Corp. Mr. Wooldridge sees a capable manager as a sort of walking, talking piece of communications equipment. He said, in a talk before IRE, "the communication function of the manager, whereby he propagates up the line to higher management the needs and ideas of his scientists and engineers, and interprets down the line to the scientists and engineers the nontechnical needs of the company heads, is almost certain to be done improperly unless the communicator is matched in impedance, not only to his superiors but also to those whom he is attempting to manage." We can think of a few other electrical quantities a manager must handle—such things as reluctance, resistance, hysteresis, and even short circuits.

How to Get Machine Design

Often letters come to us asking "how can we get regular monthly copies of MACHINE DESIGN? The procedure is fairly simple, if you qualify. MD is sent at no cost to engineers who design all types of machines, appliances, electrical and mechanical equipment. Free copies are sent to companies in the United States and Canada, *employing* 20 *or more people,* and where design engineering of products is performed. These copies are sent to management, design and engineering personnel on the basis of one for each group of four or five readers. Also, consulting and industrial engineering firms, research institutions and U. S. government installations are eligible if design engineering of products is part of the operation. However, if you want a personal copy sent to your home address, or if you don't qualify under the previous "rules," you'll have to pay the current subscription price of $10 per year. If you need a copy of your own, write to our circulation manager at the address shown in the right-hand column.

This Month's Cover

Two primary design areas of concern to every engineer are materials and production processes. This month, cover artist George Farnsworth has epitomized the close interrelation of the two. The cover epitomizes the group of 15 articles, Page 156, on "Production Characteristics of Engineering Metals."



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BPA NBP

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Advertising and editorial content itemized for convenience when studying specific design problems

(*Concluded on Page* 10)

Here's GREATER POWER for you ... in a MORE COMPACT DESIGN

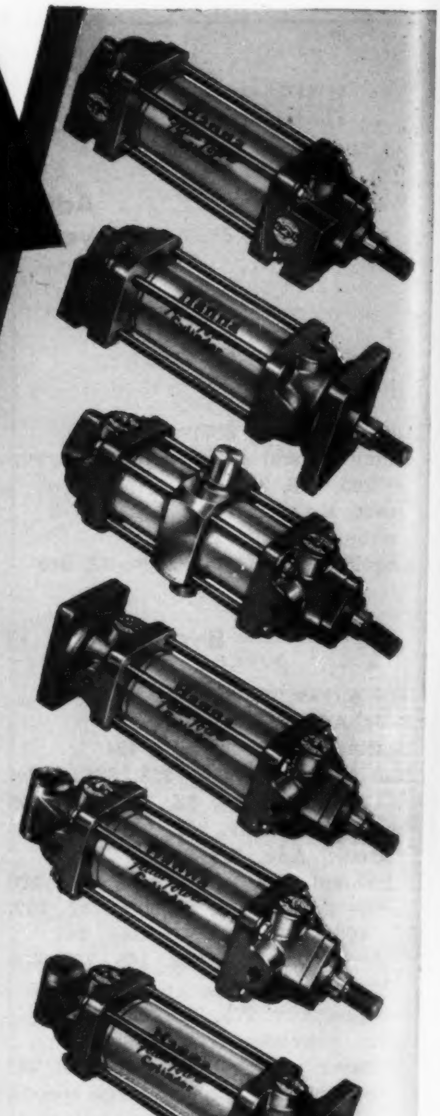
FEATURES YOU WILL LIKE:

- Greater power from a more compact design.
- Resistance to corrosion throughout.
- Positive sealing with minimum friction loss.
- Materials selected for strength, durability and long cylinder life.
- Interchangeable heads and mountings.
- Conformation to J.I.C. Standards.
- Automatic compensation for rod packing wear.
- Built-in piston rod scraper to prevent dirt and abrasives from scoring rod or damaging packings.
- Adjustable cushions of unique design.
- Wide choice of operating pressures; Air to 250 psi; hydraulic to 750 psi.

The New HANNA T 750 Series *Fluid Power* CYLINDERS

● You'll find some unique and very interesting operating features in these new Hanna T750 Series Fluid Power Cylinders . . . features that will help you solve many of your cylinder application problems more easily and more simply. The new Hanna T750 Series comes in a range of capacities, sizes and mounting styles—for air operation up to 250 psi and hydraulic operation up to 750 psi.

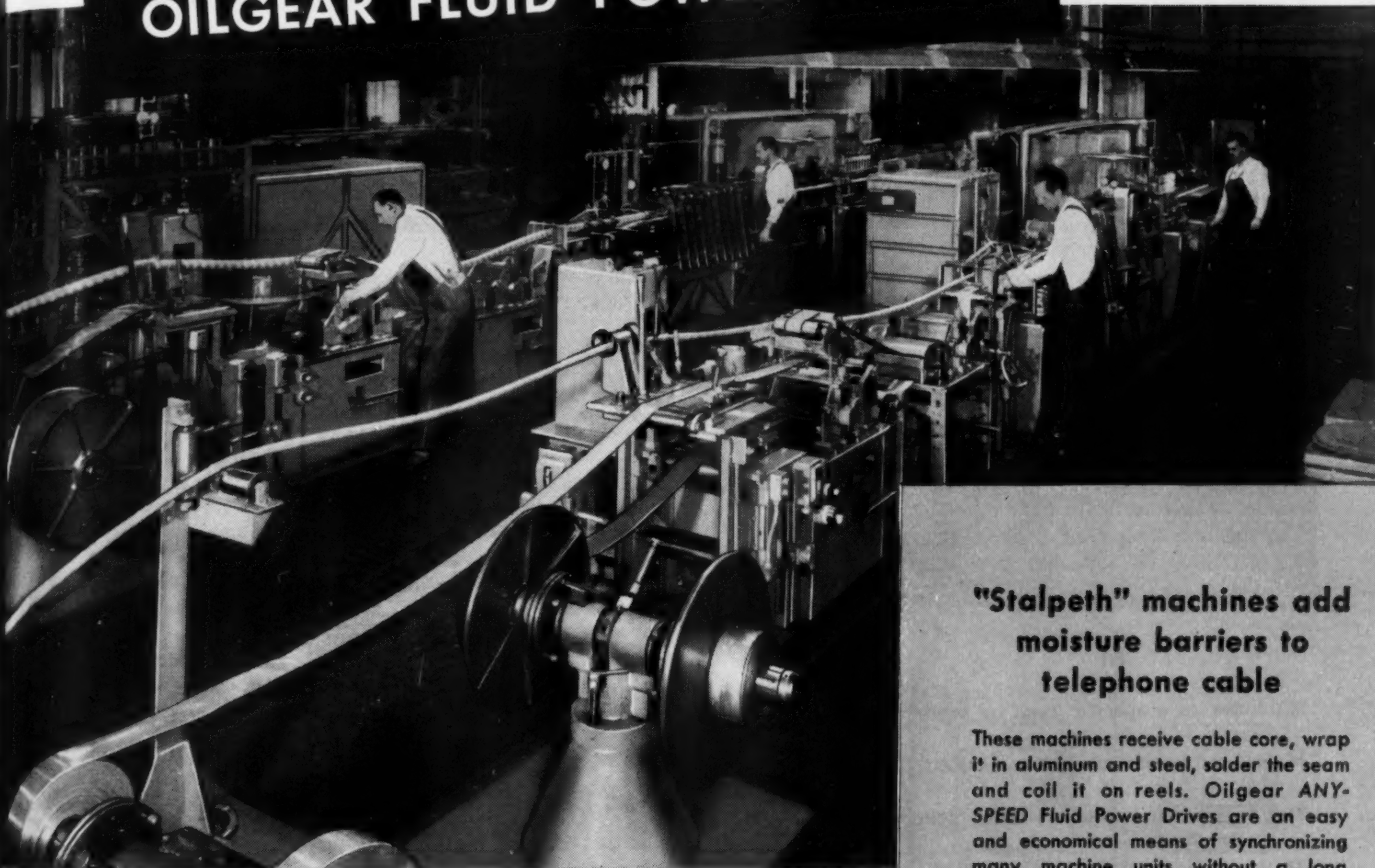
For details, ask your Hanna Representative (see your classified telephone directory), or write today for a copy of the new T750 Fluid Power Cylinder Catalog. No obligation.



Hanna Engineering Works

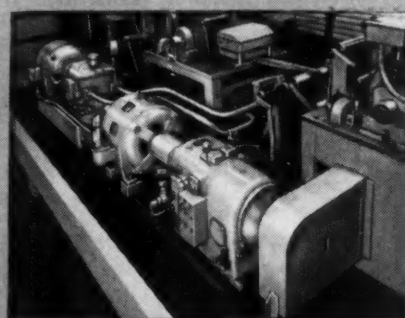
1751 Elston Avenue, Chicago 22, Illinois

OILGEAR FLUID POWER DRIVES

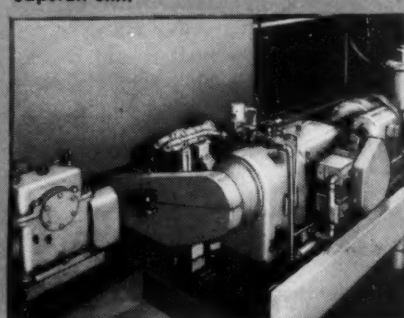


"Stalpeth" machines add moisture barriers to telephone cable

These machines receive cable core, wrap it in aluminum and steel, solder the seam and coil it on reels. Oilgear *ANY-SPEED* Fluid Power Drives are an easy and economical means of synchronizing many machine units without a long lineshaft.



These Oilgear *ANY-SPEED* units drive the aluminum and steel corrugator units in perfect unison with the governing capstan unit.



The Oilgear *ANY-SPEED* capstan drive. Not shown here is another Oilgear unit driving the cable winding reels.

Solving the problem of close synchronization of driven members

As machines become more and more complex, combining more and more functions into a single unit, the problem of driving these machines successfully becomes more difficult.

This problem confronted Western Electric Company engineers in designing what they call their "Stalpeth" machines, two of which are shown above. These machines combine corrugating of steel and aluminum strips, forming them around the cable core, soldering the seam and then winding the assembly on reels at the far end. All of the members of the machine must be synchronized to the speed of the capstan unit. Going by their experience with other somewhat similar machines, Western Electric engineers again turned to Oilgear *"Any-Speed"* Fluid Power Drives, to solve what is really a complex problem ordinarily. Oilgear units provided an easy and economical means of synchronizing many machine components.

Oilgear *Any-Speed* Fluid Power Drives and transmissions *do* offer many machine design advantages including ease of control and synchronization of driven members, steplessly variable speed, fundamentally simple circuits, and long, trouble-free life. Write for Oilgear drive bulletins. THE OILGEAR COMPANY, 1568 W. Pierce St., Milwaukee 4, Wisconsin.

OILGEAR
Fluid Power

PIONEERS . . . NOW THREE PLANTS FOR FLUID POWER

PUMPS, MOTORS, TRANSMISSIONS, CYLINDERS AND VALVES

INDEX

(Concluded from Page 7)

MACHINE DESIGN is indexed in Industrial Arts and Engineering Index Service, both available in libraries, generally

Engineering News Roundup

Higher Power Transistors May Replace Dynamotors

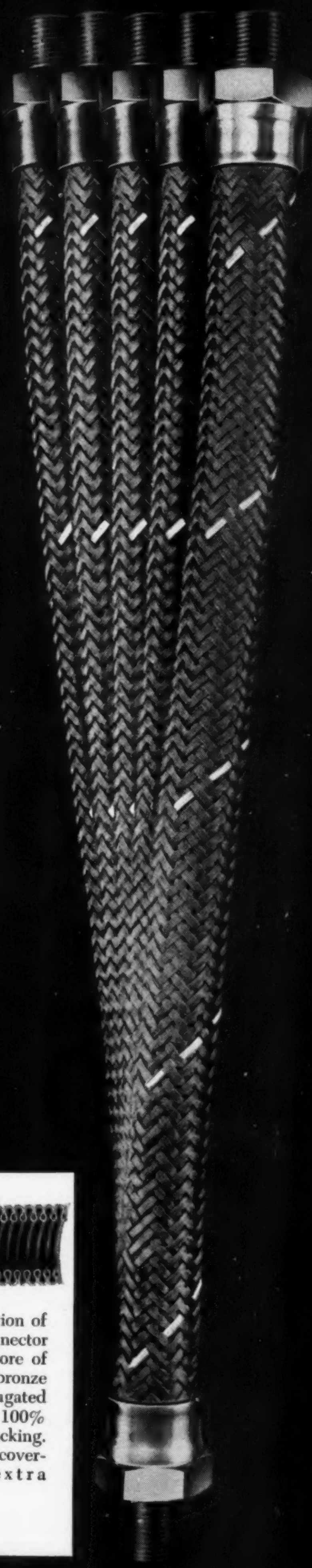
New high - power transistors show promise of eventually being able to handle sufficient power to replace high-power vacuum tubes. Developed under Signal Corps sponsorship by Transistor Products Inc., the transistors were tested recently at the Signal Corps Engineering Laboratory at Fort Monmouth, N. J.

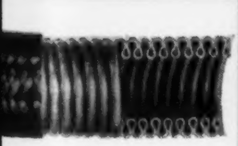
Although their major importance may lie in their potentialities as replacements for high-power vacuum tubes, a more immediate application is aimed at replacing moving parts in certain types of equipment with static parts. In tests, the new transistors were found to be capable of handling sufficiently high power to be substituted for dynamotors and vibrator power converters presently in Army use.

The new transistors have no moving parts, are said to be one-third the size and twice as efficient as vacuum tubes, and operate on greatly reduced power. Their ruggedness points to long, trouble-free life. Less drag on a battery results because they draw only a fraction of the initial current surge found in the dynamotor or vibrator.

Combined with a circuit recently designed by the Signal Corps, the high-power transistors also are being put to experimental use in

EXTRA PUSH is given this new Fairchild C-123B assault transport with wingtip-mounted turbojets. An additional 2000 lb of thrust is provided in takeoff, enabling the pilot to increase his rate of climb approximately 300 per cent. With one engine feathered, rate of climb was increased from 150 fpm to 500 fpm. Remote-controlled seal-off doors on the turbojets close the air intake scoops to reduce drag when the units are not in operation. Units operate on regular aviation gasoline





Cutaway section of Flexpipe Connector shows how core of seamless, tin bronze tubing is corrugated for flexibility. 100% tight. No packing. Wire braid covering for extra strength.

NOW...a new, standard *flexible* connector to save the cost of special design

FLEXPIPE* permits travel . . . absorbs vibration . . . connects misaligned ports in pipe lines

Here's a new, *standard* tin bronze flexible connector you can use to convey air, gas, oil, steam or water. Flexpipe Connectors have standard plated brass pipe fittings at each end. They permit travel, flex with motion, and dampen vibration. They save time and materials by taking the place of rigid connections made up on the job with elbows, couplings and short runs of pipe. When intermittent travel occurs, Flexpipe Connectors move with the pipe, relieving stresses which shorten the life of rigid connections.

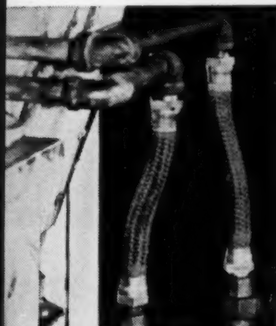
Flexpipe Connectors are designed for wet heating systems, and for trouble spots in commercial and industrial piping. Sizes, lengths, part numbers and operating pressures are given in the table below.

I.D.	Max. Offset each side of C/L (intermittent travel)	Over-all Length Inches	Part Numbers	Max. Working Pressure at Room Temp. PSI	Max. Working Pressure at Max. Temp. (350°F) PSI
1/4	1/2 1 1/4	8 16	1/4 M-10 1/4 M-20	1200	850
3/8	1/2 1 1/4	9 18	3/8 M-10 3/8 M-20	1000	700
1/2	1/2 1 1/4	10 20	1/2 M-10 1/2 M-20	750	525
3/4	1/2 1 1/4	11 22	3/4 M-10 3/4 M-20	600	425
1	1/2 1 1/4	12 24	1 M-10 1 M-20	550	375
1 1/4	1/2 1 1/4	13 26	1 1/4 M-10 1 1/4 M-20	300	200
1 1/2	1/2 1 1/4	14 28	1 1/2 M-10 1 1/2 M-20	275	175
2	1/2	18	2 M-10	200	125

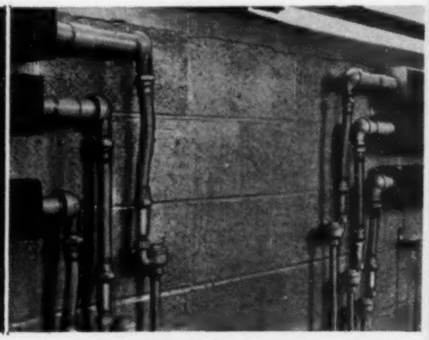
SOLD BY leading wholesale distributors who can show you samples and answer questions about service applications. For the name and address of the distributor serving your area, or for more detailed engineering information, write to *The American Brass Company, American Metal Hose Branch, Waterbury 20, Conn.* In Canada: *The Canadian Fairbanks-Morse Co., Ltd.*

55204

*Trade Mark



. . . connects misaligned condensate drains



. . . connects finned tube radiators to steam supply

Flexpipe AN ANACONDA® PRODUCT

the fields of guided missiles and radar-controlled beacons. Further study of their capabilities may lead to entirely new types of equipment not presently feasible with vacuum tubes.

Flash! MACHINE DESIGN Wins Editorial Awards

As we went to press, we received word that MACHINE DESIGN has won two awards in the 17th Annual Business Paper Editorial Achievement Competition.

First prize, in the form of a plaque, was awarded for the best single issue of 1954. Our May special issue on "Engineering Materials" took this one.

"Adjustable Speed Electric Motor Drives," appearing in October, 1954, won a second-award certificate for the best single article. We'll have more details next month.

Superfast Counter Counts Almost Anything

Up to 1 million objects of variout sizes and shapes can be counted in less than one second with a newly developed electronic counting device. Nuts and bolts, stars, blood cells or impurities in food are among the objects on which the instrument may be used, it is claimed.

Developed by Allen B. DuMont Laboratories Inc., the Iconumerator operates on the flying-spot scanning principle. Objects to be counted are placed in a special compartment. A beam of light from a cathode-ray tube scans the compartment line by line. Changes in intensity of the reflected light are picked up by a photocell through an appropriate optical system. This signal is then fed to proper electronic circuits that convert the information into numerals—either on an electronic counter or a printed tape.

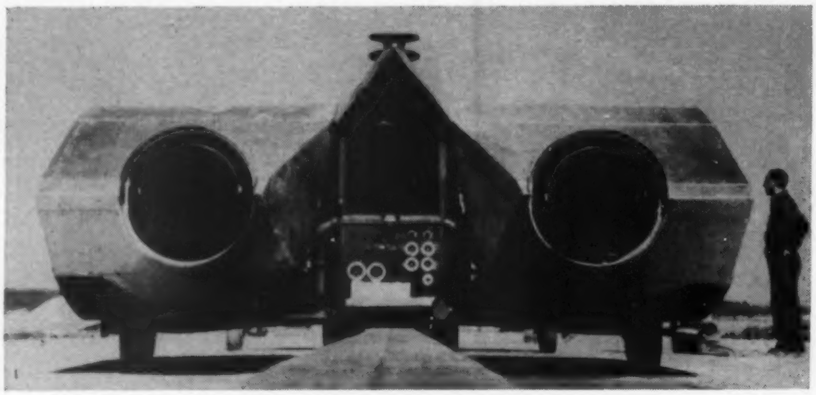
Adjustments are provided to enable the device to count large or small objects. Irregularly-shaped objects, disks perforated with holes, or objects that overlap are said to be counted as individual pieces. Combinations of large and small objects may be counted with proper circuit modifications.

DuMont's superfast counter shown here counts the number of objects shown on the round screen in less than a second. Totals are shown on the electronic counter at the top

Particles in the air may also be counted, according to DuMont. Detection of excess dust in coal mines, chaff or flour in flour mills, or particles of paint or metal shavings are among the suggested applications of the counter. Quick bacteria counts, both of drinking water and milk are said possible. According to the company, the instrument is expected to be useful in industry wherever rapid counting of objects is necessary.

PLASTIC BUBBLE encloses a controlled atmosphere in which titanium can be welded. In a molten state, titanium absorbs gases that tend to make it brittle. To avoid this difficulty, Solar Aircraft Co. has devised this plastic tent in which large components can be welded in a carefully controlled atmosphere

American Nuclear Society will hold its first professional meeting at Pennsylvania State University, June 27-29. Papers presented will deal with data not previously published in the nonsecret literature of atomic energy. Detailed information may be obtained from Professor W. W. Miller, Pennsylvania State University, State College, Pa.



JET CAR shown here is powered by two Allison J33-A8 engines having 10,000 lb combined thrust. Made by All American Engineering Co., the car is used as a means of propelling a large mass at aircraft landing speeds for testing aircraft arresting gear

New Laminates for High Temperature, Humidity

Three new grades of thermosetting laminated plastics utilizing a DAP (diallyl-phthylate) resin base are now being produced by Synthane Corp. Developed as the answer to a number of design problems involving moisture, the new laminates show promise in many types of electronic devices with particular emphasis on components used in damp, humid climates.

The new grades are coded according to filler material. DAP-impregnated canvas is called Grade C-104, Orlon is Grade O-104 and woven glass cloth is G-104. Due to its canvas filler, C-104 is easily machined and has a high degree of dimensional stability. Power factor and dielectric constant of O-104 show very little change after NEMA water immersion tests. Grade G-104 possesses the best electrical properties in the dry condition compared to other DAP grades, but shows a somewhat higher rate of change when subjected to moisture.

Maximum operating temperatures vary slightly between grades. Laboratory tests indicate that Orlon DAP will withstand continuous temperatures of 225 F; canvas 275 F; and glass fabric 325 F without affecting either the mechanical or electrical values.

The new DAP laminates are available in sheet and tube form or as parts fabricated to specifications. Sheet thickness ranges from 1/32 to 1 inch in the case of canvas and Orlon.

Third Human Engineering Institute will be held June 6-10 in Stamford, Conn. In conformance with recent developments in human engineering, the course this year will be on an advanced level. Sessions will deal with techniques for developing, determining and evaluating design requirements, experiments in obtaining design data, factors influencing design decisions and effects of personnel specifications on design. Further information may be obtained from Dr. Martin A. Tolcott, Dunlap and Associates Inc., 429 Atlantic St., Stamford, Conn.

An Industrial Standardization seminar conducted by Dr. John

TWO HALVES make up this plastic truck body. While most conventional truck bodies are made up of many pieces and sections, this milk-truck body is said to be the first fabricated from only two halves. Made from reinforced glass fiber called Lamicor by the Strick Co., the body was found to have good structural strength as well as good thermal insulating qualities. Structural framing is molded into the outer skin rather than being formed to it by riveting or molding

From the collection of Paul J. Westergard, New Jersey Arms Collectors Club. Maker: Samuel Evans, Cambridge, England, 1800-1820 Prints of this illustration suitable for 11 by 14 frame available on request on company letterhead.

Choose your weapon.....

TO COMBAT FRICTION

Armed with the proper weapon you'll always be the winner in the unending duel of friction versus lubrication. There's never a misfire when you specify Bound Brook Oil-less Bearings, for Bound Brook offers you a bearing specifically designed for every application. *Where high shaft speeds and minimum friction are the prime requirements, COMPO Porous Bronze Bearings are consistent winners. Or, to combat shock loads as well as friction, it's hard to beat POWDIRON Sintered Iron Bearings for heavy-duty installations where tensile strength is the principal factor.* Both POWDIRON and COMPO bearings are available in sleeve, flange and self-aligning types in a wide range of alloys and sizes for every known application. Write or phone your nearest Bound Brook Man.

BOUND BROOK

BOUND BROOK OIL-LESS BEARING CO., EST. 1883, BOUND BROOK, N. J.

Pioneer in

POWDER METALLURGY BEARINGS + PARTS

Gaillard will be held June 13-17 at the Engineering Societies Bldg., N. Y. Consisting of ten conferences, the seminar will cover both the engineering and management phases of standardization. Special emphasis will be placed on the organization and procedure of a company standards department. Further information may be obtained from Dr. John Gaillard, 400 West 118th St., New York 27, N. Y.

BOUNDARY LAYER CONTROL system has been incorporated into this new Lockheed jet trainer. Compressed air is bled from the engine into a tube running inside the trailing edge of the wing. The compressed air is then blown out slots in the tube over the wing flap and aileron. This blowing effect is said to make the normal air flow over the wing hug the surface, increasing lift and decreasing stall characteristics

Engineers Get Higher Starting Salaries

Starting salaries for engineers have again increased. Results of a recent survey of the 95 engineering graduates at Illinois Institute of Technology indicate that January graduates are doing pretty well.

Average starting salary for the class is $383 per month. A breakdown of the major engineering fields is:

Field of Engineering	Monthly Salary
Chemical	$398
Mechanical	392
Electrical	386
Civil	378
Industrial	353

Biggest increase over last year went to the mechanical engineers. Their January, 1954, average starting salary was $370 a month.

While the national average is estimated to be $360, the higher average starting rate for IIT graduates is said to be due to work experience prior to graduation. Many of the students are said to have the equivalent of a full year's experience by the time they graduate.

Cold-Formed Titanium Sheets Possible

Titanium sheets can be cold formed into curved cylindrical shell beads by a new process developed by Chance Vought Aircraft Inc. Danger of cracking of the hard-to-work metal is said eliminated.

A standard Niagara machine was adapted to do the work. The flow of metal, as it is being rolled, is controlled by two or four adjustable hoops which hold the metal on both sides of the roller wheels making the bead. The bead is rolled with the grain.

Beading and corrugating of many closed uniform sections other than cylindrical may be possible. Elliptical forms as well as kidney-shaped and irregular forms are being investigated.

Twenty million new jobs will be needed in the next 20 years according to population statistics studied by Industrial Psychology Inc. With the present U. S. population at 163.9 million, predictions call for a population of 221 million by 1975. Currently, there are 65 million employed or seeking employment; in 1975 there will be close to 85 million. Companies will have a greater selection of job applicants starting in 1955, with a spurt in 1960 and a large labor supply by 1975.

Abrasive Jet Tests Organic Coatings

Abrasion resistance of organic coatings on metals can be rapidly determined by a simple method recently developed by the National Bureau of Standards.

Essentially, the method determines the time required for a high-speed jet of fine abrasive to abrade through the coating to the substrate. Carbon-dioxide gas under controlled pressure propels an abrasive powder from a vibrating storage chamber through a nozzle onto the test specimen. A specially calibrated taper gage permits rapid adjustment of nozzle to specimen distances over a limited range of abrading angles. The end point is the first show of bare metal.

Other abrasion test procedures are available in which loose par-

ticles fall, rub or are blown against a specimen. The NBS method is similar in principle to these but is claimed to be more rapid with better reproducibility. Because the instrument simulates a wide variety of service conditions, it can be used to determine abrasion characteristics of all types of protective coatings regardless of gloss, color, thickness or surface area.

High Capacity Feature Of Miniature Recorder

A new technique developed for an airborne recorder is used in a commercial industrial item to provide 210 channels of recorded data on a 5-inch wide tape.

Designed by Radiation Inc., the unit provides an instantaneous record of up to 210 on-off operations. Electrosensitive chart paper enables the operator to have a permanent, dry record requiring no processing. Information may be visually interpreted or reduced automatically by machine.

New airborne and ground recorder having a 210-channel capacity on a 5-inch wide chart

While the lightweight unit was designed to monitor aircraft functions in flight, it is adaptable to a number of industrial monitoring applications. It may be employed as a production sequence time monitor to record operation time at each assembly line station. Other applications may include chemical-processing and oil-refining operations.

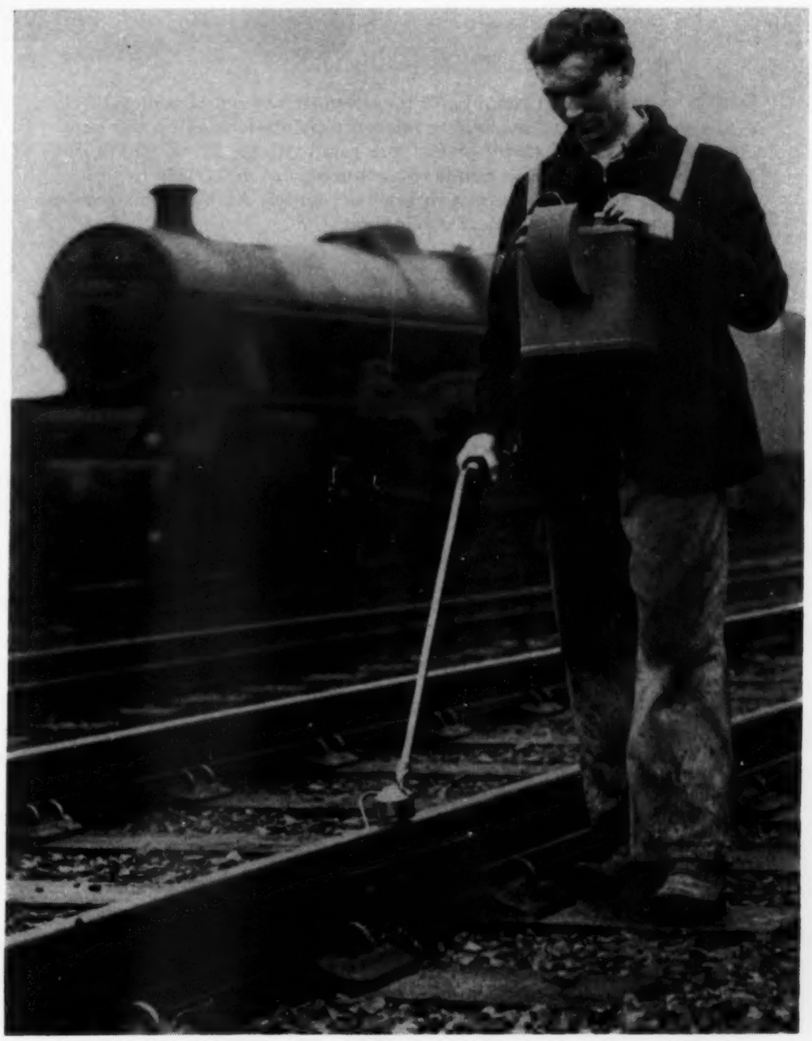
Die Casting Engineers Form New Technical Society

A new technical society, the Society of Die Casting Engineers, has been formed to foster and further technological advances in the field of die casting and finishing of metals and die molding of plastics and powdered metals. Main objective of the new society will be the exchange, accumulation and dissemination of the latest information and knowledge in the arts and sciences of die casting and related arts. A major aim is the development of modern standards for the die casting industry.

Membership is open to those whose business activities relate to die casting, die molding, finishing and related arts. National headquarters and offices of the society are at 19370 James Couzens Highway, Detroit 35, Mich.

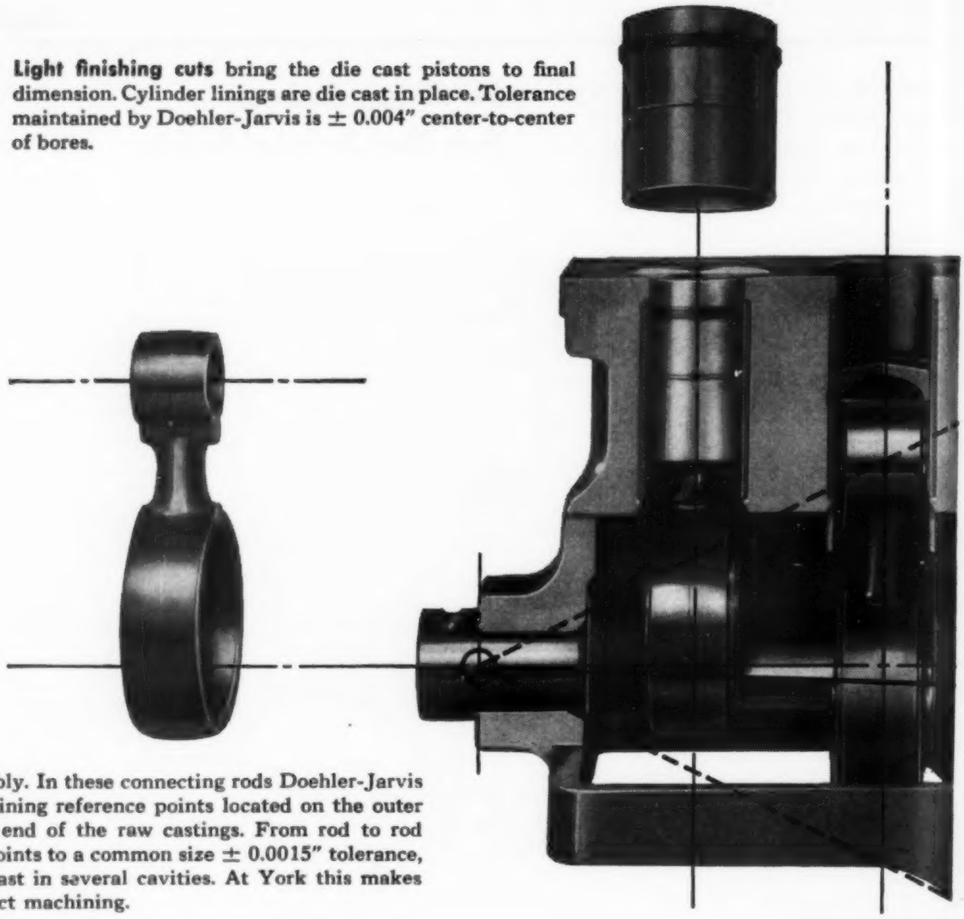
Indiana Steel Products Co. has acquired the business and plant facilities of **Ferroxcube Corp. of America,** Saugerties, N. Y.

(Continued on Page 24)



"WALKIE-TALKIE" track tester detects flaws in British railway track. As the detecting probe of this miniature device is slid along the track, an audible or visual indication is given as it passes over a defect. The unit is battery powered

Light finishing cuts bring the die cast pistons to final dimension. Cylinder linings are die cast in place. Tolerance maintained by Doehler-Jarvis is ± 0.004" center-to-center of bores.



Cast-in chamfers aid assembly. In these connecting rods Doehler-Jarvis dies also establish two machining reference points located on the outer circumference of the throw end of the raw castings. From rod to rod Doehler-Jarvis holds these points to a common size ± 0.0015" tolerance, even though they must be cast in several cavities. At York this makes for smooth, precise, low-reject machining.

How Doehler-Jarvis helped York make hermetic compressors lighter and

This is a story of practical product engineering.

Its concern is with things you may want for your product. Reduced size, weight, cost. Stepped up efficiency.

Cool! Light, small die cast compressors make York Window Conditioners compact, efficient and good for years of trouble-free service.

Increased life. These were what York Corporation wanted for its post-war "packaged" air conditioners.

And at war's end, York was ready with a revolutionary, new hermetic compressor design. Small, simple, efficient. Aluminum for lightness. Now . . . how should it be made?

Three cost factors favor die casting

1. Raw castings cost less (less metal to buy)

2. Less machining was needed (less waste, fewer man-hours)

3. Tooling requirements were lower (fewer tools, lighter and less costly)

With these factors in mind, York took their two-cylinder, ¾ H.P. compressor* as a starter and went into production. Within a few years their whole line was converted to the new die cast design. Later . . .

York sees a way to cut size and weight even more

Doehler-Jarvis was asked to incorporate compressor and motor housing into a one-piece die cast unit. A series of conferences followed.

Together, engineers from both companies solved one problem after another. Precise dimensional control. Cast-in-place cylinder linings. Die cast bearing surfaces. Concentricity and precise location of cylinder center lines. (To solve this one, Doehler-Jarvis had to provide in the

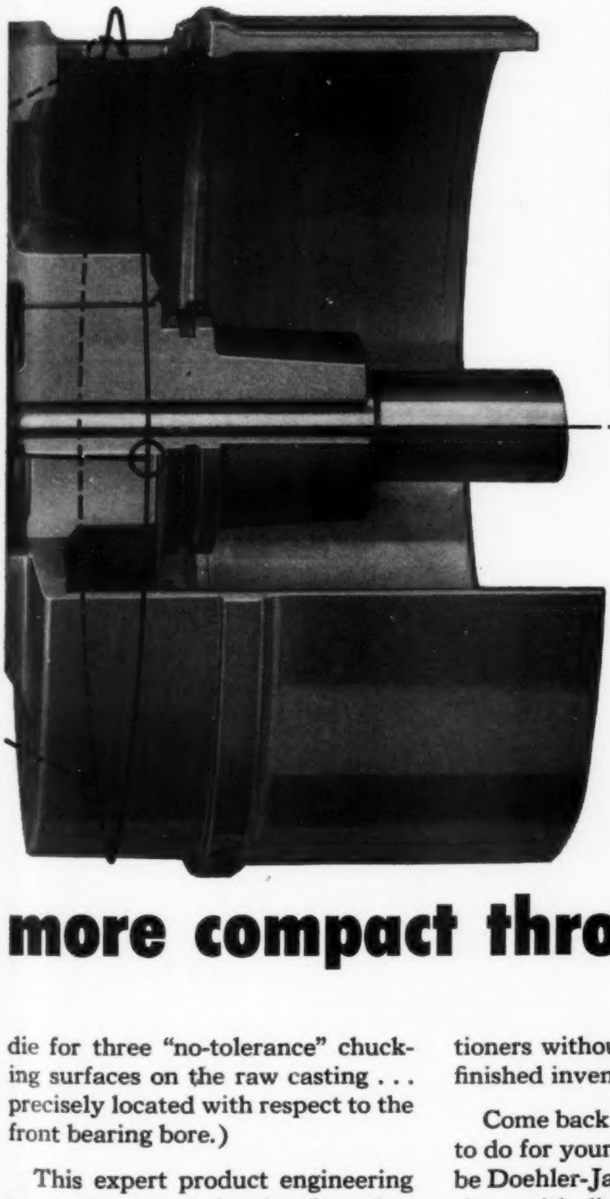
**Test units, run continuously ever since, have logged over 70,000 hours without failure.*

"Phantom" control cone, with three "no tolerance" chucking surfaces, establishes precision

In the raw casting three equidistant chucking surfaces are established by the Doehler-Jarvis die. Their centers are located on a circle concentric with and exactly perpendicular to the shaft. The plane thus established forms the base of a "phantom" control cone (see illustration) whose apex is at the small bearing bore.

From this cone as a reference, all center lines and true surfaces throughout the piece are established. All machining setups, too, are based upon it.

At the Doehler-Jarvis plant, great care is taken to hold the chucking surfaces true. Aside from very slight variations in cooling, no tolerance is allowed. As a result, York machining proceeds smoothly with minimum rejects at every stage. What's more, the resulting precision insures long wearing bearings, long life pistons and cylinders.



more compact through die casting

die for three "no-tolerance" chucking surfaces on the raw casting . . . precisely located with respect to the front bearing bore.)

This expert product engineering team went on to develop for other sizes other integrated die cast housings, and the connecting rods, pistons, main bearings, and oil slinger rings. These compressors are light, compact and highly efficient. They can be produced quickly and easily.

"Cannot be matched for low cost," York says

"What's more, because the parts can be die cast in a hurry . . . and because Doehler-Jarvis never fails us on delivery . . . we stay flexible. We're able to meet peak demands for air conditioners without going overboard on finished inventory."

Come back to the things you want to do for your own product . . . maybe Doehler-Jarvis could help you do them with die castings. We've done it for scores of manufacturers, large and small—including makers of home appliances, office and public utilities equipment, industrial machines, and many other similar products made better with die castings.

So, if you are engineering a new product or improving the one you have, call in Doehler-Jarvis. With more than fifty years experience behind us, we may be able to contribute in many ways.

®

Doehler-Jarvis Division

of

National Lead Company

General Offices: Toledo 1, Ohio

(Continued from Page 21)

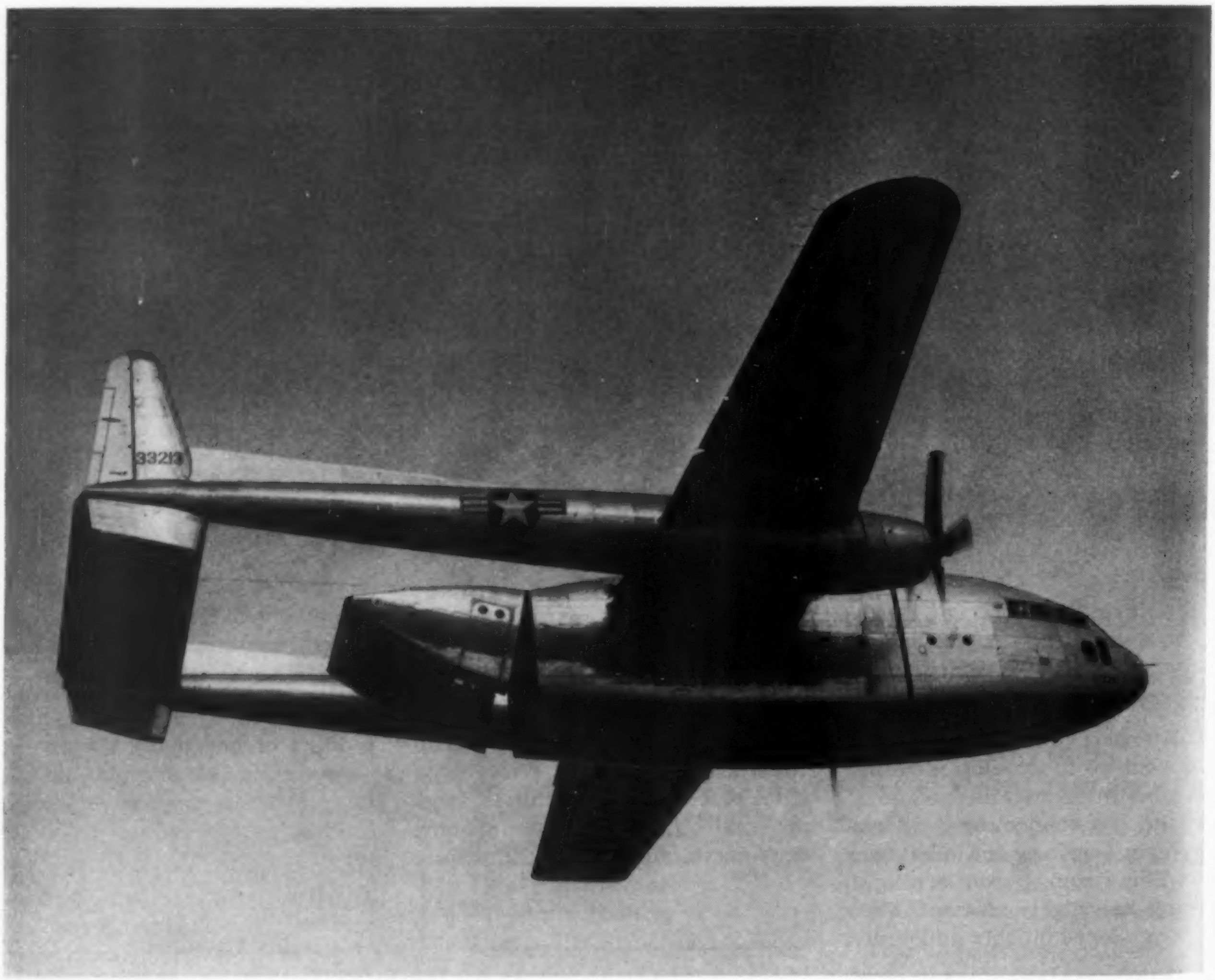
New Process Makes Stainless Surface Alloy

Chromium diffused into ferrous metals has been found to form a stainless surface alloy that resists corrosion. Developed by Alloy Surfaces Co., the process is said to permit ferrous metals to resist corrosion under severe atmospheric, water and chemical corrosion conditions.

A stainless alloy is formed in the surface to a depth of 0.001 to 0.008-inch without causing dimensional changes. Bending, stretching or twisting the processed metal does not crack or chip the surface, according to the company. Products can be welded before or after processing. Mild-steel welding procedures are used before processing and stainless-steel procedures are used after processing.

Parts and assemblies can be made with the resistance characteristics of stainless steel at less cost than stainless-steel fabrication, it is claimed. Some of the applications include nuts, bolts, washers, clamps, tools and dies. Specification gray-iron and malleable-iron castings, and Meehanite, can be treated to make castings with corrosion resisting properties.

AGMA Index shows volume for the gearing industry to be increased by 5.4 per cent in February 1955, as compared with January. The index figure for February is computed to be 148.5. AGMA



BREAKING IN TWO? No, this is a newly designed flight-opening cargo door. Installed on a Fairchild C-119 Flying Boxcar, the door is movable to meet a variety of in-flight operational situations. The bottom section may be retracted into the upper section to provide an opening for paratroop operations or release of small bundles. A second in-flight configuration allows the entire upper section of the door to be raised to provide an unobstructed opening the height and width of the fuselage for dropping of heavy equipment. Doors are operated hydraulically

index figures are computed using the 1947 to 1949 period as a base of 100.

World Plastics Fair and Trade Exposition has been postponed from April 6-10 to October 5-9. The new dates will provide more time for plastics manufacturers, machinery firms and resin suppliers to ready exhibits for the exposition, which will still be held at the National Guard Armory in Los Angeles.

"I want a cam that will give this motion."

Award Given for Welded Thrust Bearing Design

One of the award-winning designs in the James F. Lincoln Arc Welding Foundation competition describes a welded thrust-journal bearing. No known attempts have been made to use such construction in housings for combined thrust and journal bearings of the heavy type used in marine applications.

This housing design has met all tests successfully in electrical ship propulsion equipment. Dimensionwise, it is 27 inches long, with a 20-inch diameter bore in the central section. Base plate is 2 inches thick; other roll-formed and flame-cut plate elements vary down to about 1 inch thick. Welds are mostly $\frac{1}{4}$, $\frac{3}{8}$ or $\frac{1}{2}$-inch fillets. Principal feature is the oil-tight welds, accessible and observable

on the exterior of the housing.

In operation, the double-acting bearing receives the full forward and astern propeller thrust. A rotating collar is attached to the shaft; on each side of it are stationary babbitt-faced shoe segments, along with load-equalizing mountings for the shoes. The housing also contains the journal bearing which supports the radial load of the shaft. Oil is circulated through the entire bearing cavity.

New Nylon Offers High Strength, Clarity

Specialized properties of a new nylon material are expected to increase use of this plastic in many fields. Called Plaskon Nylon 8200, the new compound is made from caprolactum. It is said to have a high molten viscosity and be particularly adapted to extrusion, injection and blow molding.

Its producers, Barrett Div. of Allied Chemical & Dye Corp., have found that maximum impact strength with minimum mold shrinkage can be obtained with low mold temperatures. While 8200 becomes more rigid at higher mold temperatures, it was found that it does not become brittle at temperatures as high as 200 F. Because crystallization of thinner sections is stopped quickly at low mold temperatures, high clarity results. This property of controlled crystalline structure is said to enable the molder to vary the final physical characteristics of thin sections.

Voids in large pieces are said minimized with the use of Plaskon Nylon 8200. It has been found that this new compound does not decompose nor liberate gas during the molding or extrusion cycle. In most cases, the makers say, voids due to trapped air are eliminated.

Color may be added after molding. By cold-coloring, a few millimeters depth of color will result. Full color may be obtained by blending the color with the charge before molding. Natural color of molded Plaskon nylon parts is opaque white.

Full recovery of sprues, runners

or spoiled pieces is claimed possible without development of color. As a result, a yield of nearly 100 per cent on each pound of material is said possible.

Besides having properties characteristic of all nylon parts, 8200 also has high strength, impact resistance and abrasion resistance. As a film it can be made thinner for use in laminating materials, tapes, or as sheeting for conveyors. It is already in use for bottles for chemical packaging.

Nonmilitary Reactor To be Constructed

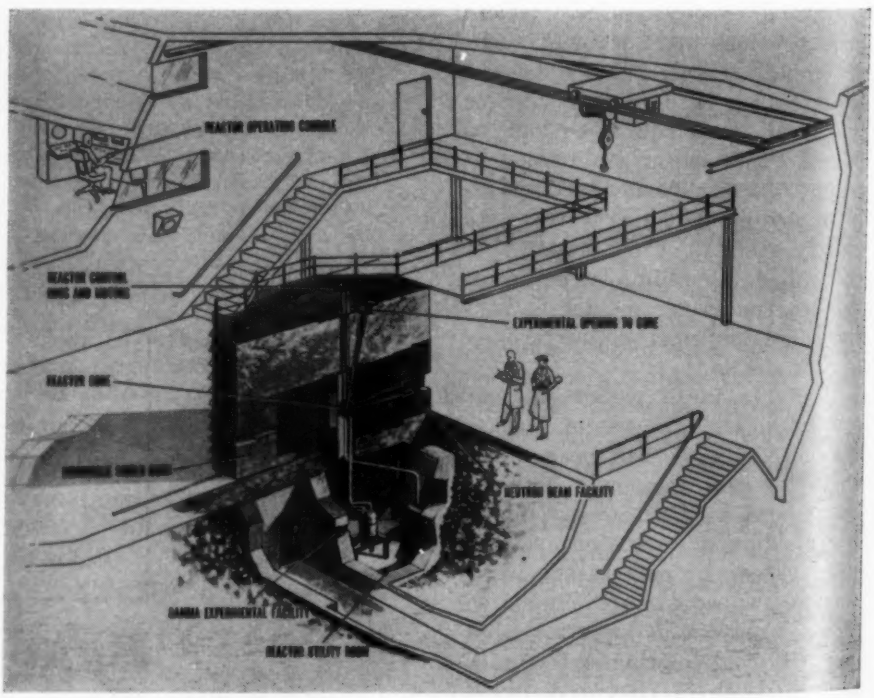
Designed for private industrial research, a new reactor to cost $500,000 will be built for the Armour Research Foundation and located on the Illinois Tech campus. North American Aviation Inc. has been awarded the construction contract, with completion of the reactor scheduled for the end of 1955.

Expected to operate at a power level of 50,000 watts, the reactor will produce neutrons and gamma radiation for research and development in the fields of biology, metallurgy, food processing, electronics, chemistry, oils and gases, machinery and allied industrial and scientific pursuits.

A particular feature of the reactor is its self-contained design which confines all the radioactivity within the shield. No fumes, smoke, gases or other materials will be exhausted or discharged from the machine.

Fissionable material to fuel the reactor will be obtained from the AEC under the licensing provisions of the Atomic Energy Act of 1954.

Sponsored research with the machine will be subject to no competition from military applications, according to Armour officials. There will be no secrecy



Sketch of the first nuclear reactor to be built for use specifically in private nonmilitary research. The 50,000-watt reactor will be located on the Illinois Institute of Technology campus and will be used to investigate the structure of plastics, rubber and similar materials as well as studies of wear and friction, metals, glass and ceramics

of any kind other than that called for in the protection of the individual sponsor's programs. The machine will not be used for research on reactors nor for the generation of electrical power.

Fluid Power Group Discusses Equipment Markets

For its second annual meeting, the National Fluid Power Association met at the Broadmoor Hotel, Colorado Springs, April 4-6. Theme of the meeting was markets for hydraulic and pneumatic power and control equipment.

Newly elected officers are: president, John E. Erskine, Racine Hydraulics and Machinery Inc.; first vice president, O. Wendell Macy, Hydraulic Press Mfg. Co.; second vice president, J. J. Pippenger, Double A Products Co.; and treasurer, Ellwood G. Peterson, Hannifin Corp. Executive secretary of the NFPA is Barrett Rogers, with headquarters at 1618 Orrington Ave., Evanston, Ill.

• • • SMOOTH SOUND, *no matter how loud, sounds better than irregular noises, according to Lockheed engineers. As a result, these engineers have devised an electronic governor to synchronize airplane propellers so all the propeller tip air blasts would hit the fuselage at the same time. This, they say, reduces vibration force 75 per cent and makes the sound easier to listen to. Passengers won't mind, they say, just so the sound is pretty and loud, even though it's pretty loud.*

New Computer Solves Electrical System Problems

Solution of complex electrical system generating, transmission and distribution problems will be speeded by the new electronic "brain" now in operation at the General Electric Co. in Schenectady. Capable of remembering up to 2000 ten-digit numbers and locating any one of them in 0.003-second, the new machine fills the gap between the superspeed electronic

computers and standard punch-card type equipment.

This is the first time the new type IBM computer, known as Type 650 Magnetic Drum Data Processing Machine, has been applied to nongovernment, scientific work.

The 650 combines an advanced memory device and a stored program feature. Its ability to remember a tremendous number of complex instructions and execute them with accuracy shortens to minutes design and system engineering calculations which previously took hours to compute.

Typical of calculations the new computer performs are the determination of the most economic operation of electrical utility systems, radio interference phenomena, thermodynamic and heat-transfer problems and atomic power studies. In addition the computer will be available for product design engineers, working in cooperation with application engineers on such problems as lubrication studies on rotating machinery and turbine flow characteristics. It can also be used in conjunction with the network analyzer for solving more complex system problems.

Electronic heart of the computer is an alloy-coated, steel cylinder, which turns at the rate of 12,500 rpm. The cylinder—a "magnetic drum"—is only 16 inches long and 4 inches in diameter. On the outside surface of the drum as many as 2000 ten-digit numbers can be stored as magnetized spots, each no larger than the head of a common pin. Any number can be read, written, or erased in less than 0.003-second.

New officers of the American Society of Tool Engineers for 1955-56 are president, Dr. Harry B. Osborn, Jr., technical director, Tocco Div., Ohio Crankshaft Co., Cleveland, O.; first vice president, H. C. McMillen, plant manager, Philco Corp., Bedford, Ind.; second vice president, H. E. Collins, manager, Process Engineering Dept., Hughes Tool Co., Houston, Texas; third

(*Continued on Page* 36)

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vice president R. C. W. Peterson, president, Peterson Engineering Co., Toledo, O.; fourth vice president, Wayne Ewing, president, Arrowsmith Tool and Die Co. Inc., Los Angeles; treasurer, H. D. Long, president, Scully-Jones and Co., Chicago; secretary, John X. Ryneska, General Electric Co., West Lynn, Mass.

New order index of industrial supplies and machinery continued its climb for the fourth consecutive month in February to reach the highest point in 22 months. The American Supply and Machinery Manufacturers' Association reports the new order index for Februray at 175.1. This is the highest reported since April, 1953, when it reached 182.1. The index measures the flow of order received by Association members who are manufacturers of production and maintenance equipment, tools and supplies selling to industry through industrial distributors.

New Washer Shakes Clothes Clean

Sound rather than physical agitation forces soapy water through clothes in this newly developed British washing device. Made by G. Developments Ltd., the device vibrates at 100 cps to dissolve and remove dirt without moving the clothes. So called unlaunderable fabrics are said to come out unharmed after treatment by this virtually noiseless machine.

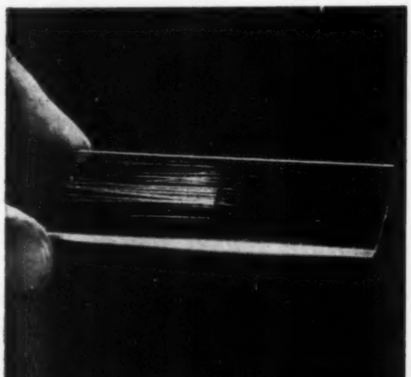
Not a supersonic device, the vibrator is a top-shaped affair that may be immersed in a sink, basin or washtub. Similarly operated units are reported used in a variety of mixing and washing applications in industry.

Eastern Industries Inc., manufacturers of hydraulic pumps, aviation products and industrial mixers, has entered the plastic laminates field by forming a new affiliate, **New England Laminates Co. Inc.** The new company will manu-

facture plastic laminates for the electrical and electronic industries, specializing in the manufacture of epoxy resin laminates and high quality metal-clad laminates used in the production of printed circuits. Other lines will include NEMA grade phenolic laminates, polyester laminates and reinforced plastic molded shapes.

New Compound Scratchproofs Glass

A new water-dilutable silicone treatment that can be applied easily to give maximum scratch resistance to glass, porcelain or china has been developed by Dow Corning Corp. Called F-4141, the treatment requires only a mild cure or none at all. It forms an invisible nonoily film which imparts a high degree of lubricity and scratch resistance.



Scratch resistance imparted by Dow Corning's new silicone treatment is shown on the right half of this glass slide. Left half was untreated

Application may be by dipping, flooding or spraying. Optimum properties are said obtained by air drying at room temperature for 24 hours or curing at 100 C for 10 minutes. According to Dow, the cured film is not affected by a 2-hour exposure to live steam and is insoluble.

Texas Instruments Inc. announced a price reduction on all its five types of silicon transistors

by 25 per cent and on both its types of silicon junction diodes by more than 30 per cent. Texas Instruments has remained the exclusive commercial source for the new high-temperature, high-frequency silicon transistor since its announcement in early 1954.

Westinghouse Corp. has formed a new hydraulic drives department to engineer, manufacture and sell hydraulic torque converters, associated brakes and transmissions. The Schneider Mfg. Corp., Muncie, Ind., a wholly-owned subsidiary of Westinghouse, has been dissolved to form this new department.

The Electric Storage Battery Co. has created a new research division on the corporate level and expanded research activities under the direction of Dr. L. E. Lighton, vice president. Research for all company divisions will be separated from development engineering and will be carried on in a new center at the company's Crescentville plant in Northeast Philadelphia.

Miniature Sealed Switch Made for Fast Operation

A magnetically-operated, glass-enclosed, dry-reed switch with an operating time of 1 millisecond or less has been developed by Revere Corp. of America. It is expected to be useful in industrial applications where a sensitive control element is required.

Barely larger than an ordinary kitchen match, the Glaswitch operates in any position at temperatures from −85 F to +500 F and at rates as high as 400 cycles per second. The switch is operated by application of an external magnetic field. Contacts are rhodium plated and operate in an inert atmosphere hermetically sealed in a glass tube, permitting safe operation in explosive atmospheres. The absence of either vapor or liquid gives virtually complete freedom from switch explosion and contact contamination. Contacts are rated at 0.5-amp resistive or inductive at 28 volts dc, or 10-watt lamp load

at 115 volts ac.

The Glaswitch has wide application as the basic component of sensitive relays, as well as control, indicating, counting, computing and similar equipment.

FLAME - CUT PARTS shown here are examples of the complex shapes that can be cut from hot-rolled steel plate. Made by the Apex Welding & Fabricating Corp., these parts are used in a Macy collator. Lower cost and faster fabrication were the reasons given for flame-cutting these pieces. Design revisions are also easily made without expensive retooling

"C. O." Eliminated

One of the metalworking industry's most annoying problems, "coolant odor," is caused by rancid water-soluble coolants. This particularly offensive odor is said eliminated with TL-131, a new cutting fluid developed by Johnson Wax Co.

Because the new coolant is all-chemical in composition, there is no decaying organic matter on which bacteria may live. Therefore, according to Johnson, there is no need for the use of formaldehyde or bactericide with TL-131.

White Motor Co. recently announced formation of a Special Products Div. to handle the development and manufacture of a diversified line of nonautomotive products. The new division will provide facilities and specialization needed to explore all the possibili-

(Continued on Page 42)

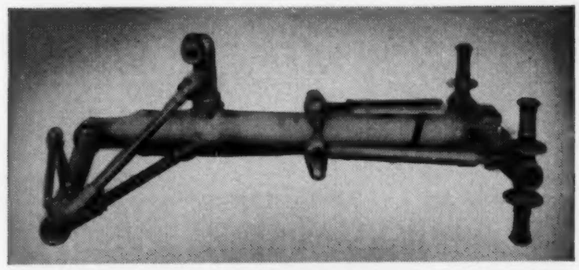
REPUBLIC STEEL

...ready with the answers to your strength-to-weight problems...

One man's problem may call for alloy steel... another's a stainless steel... and a third's a special carbon steel... all made by Republic. At Republic, we roll more types of steels and make more types of steel products than any other producer. From decades of experience with many problems and many fabrication processes, the Republic Technical Man can hand you the answer that meets your needs.

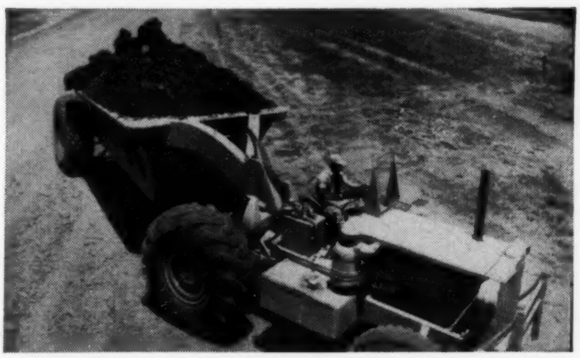
Whether your product must move lightly, stand still, look beautiful, or fight corrosion... the Republic Technical Man and his background of experience are prepared to serve you.

The coupon below will bring you information about Republic Titanium, Republic Stainless Steels, and Republic Alloy Steels.



WHAM! EVER THINK OF THE TREMENDOUS STRAIN on the landing gear when the huge aircraft you are in hits the runway at high speed? Don't worry, the landing gear can take it. Republic Alloy Steels provide the high strength and toughness needed to withstand high impact and heavy loads in aircraft landing gear—provide the hardenability to resist wear on bearing surfaces.

REPUBLIC HIGH STRENGTH STRUCTURAL BOLTS provide a new, fast, economical way to fasten structures permanently. Bolting reduces noise. Replaces field riveting. Is often safer and easier than other methods. Work usually is done from within structure, eliminating costly scaffolding. Made in accordance with ASTM Spec. A325. Bolts marked for easy identification to conform to Spec. for Assembly of Structural Joints, 2-27-54, Research Council on Riveted and Bolted Construction.



SAVE UP TO 25% IN WEIGHT, EVEN 50% with Republic High Strength Steel. Yes, when you engineer earth moving equipment, truck and gasoline trailers, railroad cars, and other mobile equipment to take full advantage of the high strength, low weight and corrosion-resistance of Republic High Strength Steel, you can cut weight up to 50%. And you can lengthen equipment life, too.

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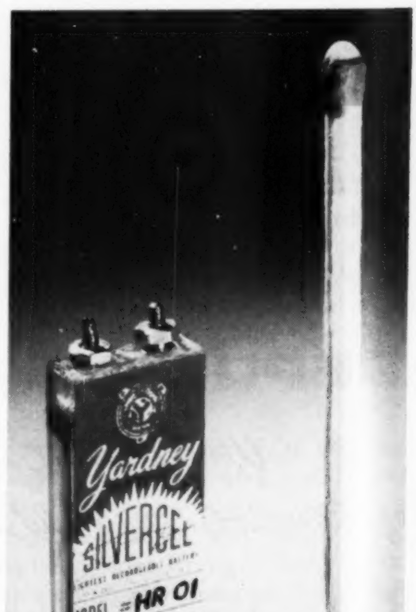
ties for new production, including newly-developed products seeking manufacturing facilities. General manager of the new division is Kenneth F. Ode, former manager of government contracts for White Motor Co.

World's Smallest Storage Battery Is Produced

A rechargeable storage battery, believed to be the world's smallest, has been developed by Yardney Electric Corp. No larger than a postage stamp, the tiny high-capacity battery was designed to power a secret instrument package for an electronics defense firm, and is ideally suited for use in portable communications, recording, telemetering and photographic equipment.

Built on a revolutionary silver-zinc principle, the new storage cell



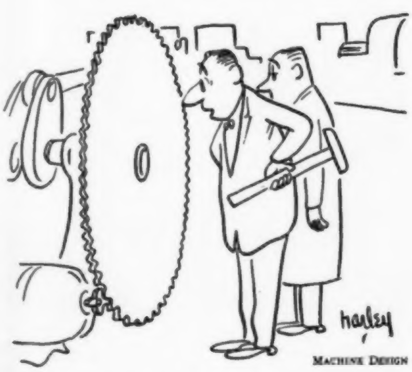
Smaller than an ordinary match, this Silvercel is claimed to be the smallest and lightest storage battery to be developed

measures 3/16 by ⅝ by 1⅛ inches and weighs only 1/6 ounce.

Designed for telemetering, volt-

age reference and instrument applications, the 0.1-ampere-hour cell provides maximum continuous drains of 500 milliamperes and peak pulse currents in excess of 2 amperes. This makes the battery extremely suitable for applications requiring high current output. The miniature cell features extremely flat voltage output. This close regulation is of major importance for voltage reference applications and wherever constant speed or intensity is required.

It is estimated that this battery could operate an electric wristwatch for more than a year before requiring recharging.



"I wonder if we couldn't work out a better gear ratio."

New Method Insulates High-Voltage Motors

A new insulating system for large motors or generators has been announced by Allis-Chalmers Mfg. Co. Said to be the first all-silicone-rubber insulation, the new system completely seals the stator coils. Known as the Silco-Flex system, the insulator is now available for all Class H insulated form-wound coils and for certain Class A and Class B windings.

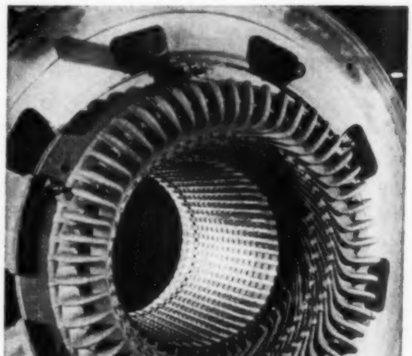
Based on Dow-Corning's Silastic silicone rubber, the insulating material is applied to the conductors and vulcanized into a homogeneous mass. The result is a sealed dielectric barrier claimed to be impervious to moisture and

News Roundup

heat. Conventional high-temperature insulating systems have been built up of combinations of mica, glass and binders.

Dielectric properties of the insulation have been found not to change significantly with aging at temperatures up to 250 C. Surface resistance remains high under moisture condensing conditions that may cause other insulations to flash over.

Coils insulated with silicone rubber have been found to have



Stator for a 2500-hp, 2300-volt squirrel-cage induction motor treated with Silco-Flex all-silicone-rubber insulation

greater resistance to abrasive dusts than conventionally insulated coils. Because of the resilience of Silco-Flex, it will withstand mechanical abuse due to stresses caused by overloading and rapid starting or stopping of equipment.

Outstanding resistance to atmospheric contaminants, corona and weathering are among the features of the new insulating system. Cooler operating temperatures result from the improved heat-dissipation characteristics of the material.

Some applications that formerly required totally enclosed frames may now be handled with semiprotected or open type frames. Motors in cement, crushing and similar machinery are said able to retain overload capabilities where ventilation has been inadvertently reduced by accumulation of dust

in the ventilating passages.

At present, Allis-Chalmers is building machines in the 2300 and 4000-volt class wound with Silco-Flex insulation. Eventually the insulation is expected to be applied to a wider range of motor types and ratings.

• • • FASTER LIGHT, *discovered since the war, has been verified by recent tests at the National Bureau of Standards. A value of speed of light of* 299,776 ± 4 *kilometers per second was generally accepted as correct before the World War II. Since then, an average value of* 299,793 ± 1 *kilometers per second has been measured. More accurate systems of measurement are said to account for the increase.*

Institute to Study More Human Engineering

Because business and government leaders want to learn more about efficient human operation, Franklin Institute is expanding its section on Engineering Psychology. The problems to be studied include the measure of man's performance and his potentialities.

According to Dr. Henry B. Allen, director of the Institute, engineering psychology has many practical applications. Some of these applications are (1) designing equipment for more efficient human operation, (2) determining the conditions for optimal operation of systems of men and machines, (3) determining human preferences and (4) designing and analyzing experiments.

Problems to be investigated will involve more than merely personnel selection, time and motion studies, job analyses and product design. Both classical and modern scientific techniques will be used in the studies.

Engineers Told To Learn Management

Five new outstanding calls upon American engineering—for leadership, training, sharing, conserving,

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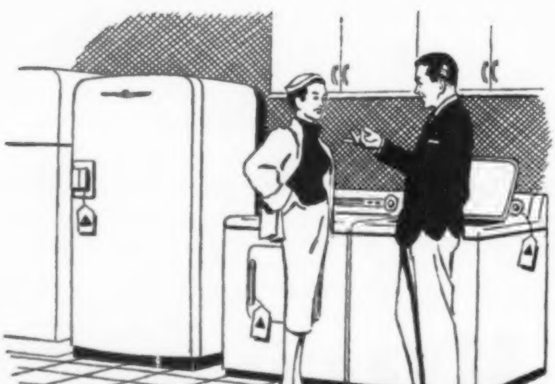
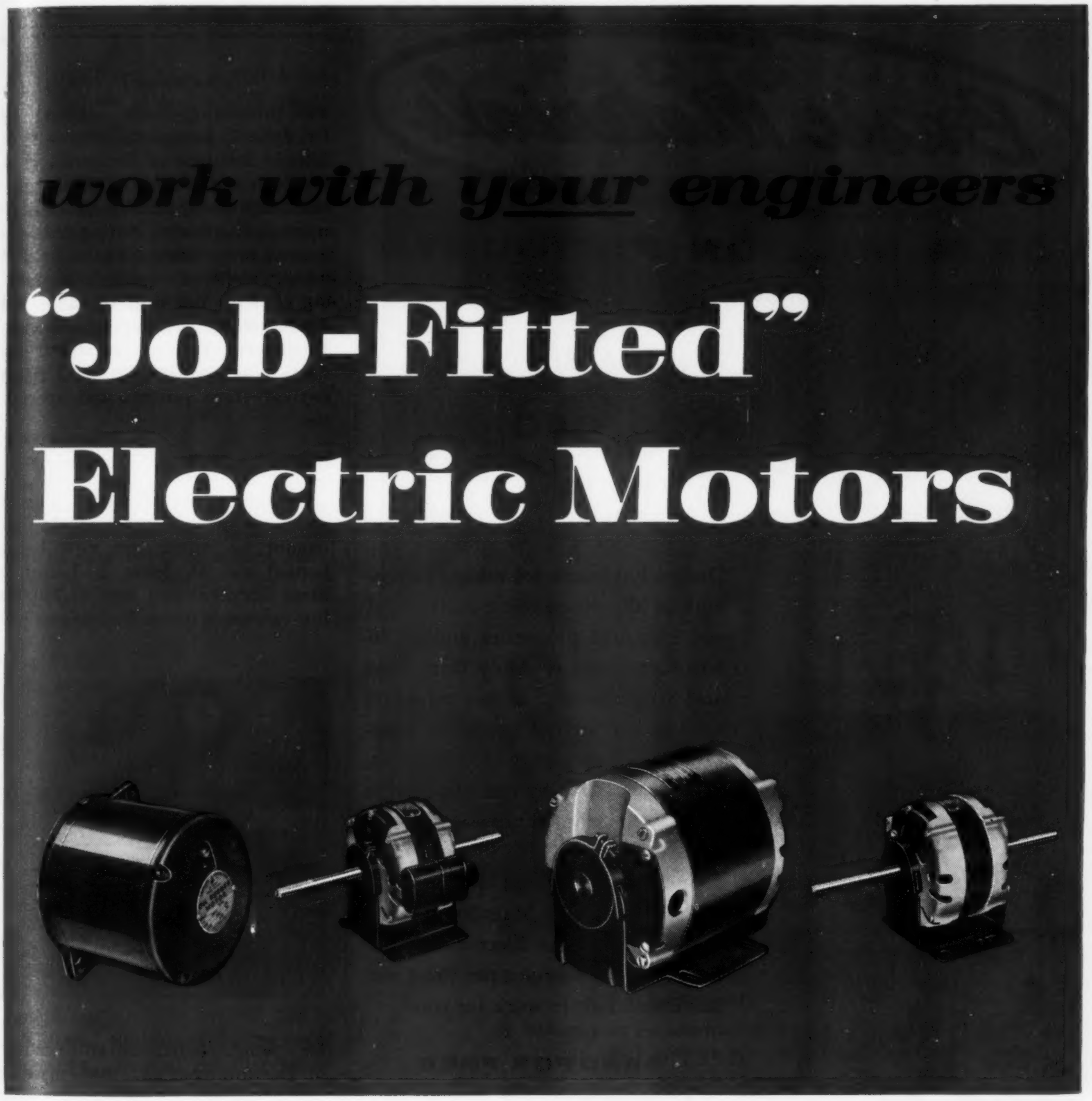


"The lady who is wise will ask to be advised if it's powered with a Delco Electric Motor."

"Job-fitted" Delco Electric Motor performance for your product begins on *your* drawing board. Mechanical fitness and correct electrical adaptation are proved in *your* laboratory.

Through each step from design to production, Delco engineers work with your engineers to make *sure* every Delco Electric Motor exactly

★ ***See Delco Electric Motor advertising in The Saturday Evening Post and Better Farming for the full Delco story.***



fits your own application and requirements. And for on-time delivery of motors—in any quantity, wherever you want them—you can depend on Delco.

That's why Delco Electric Motors power more nationally famous appliances than any other make—why it's "Delco Preferred" in industry.

From small fractionals to giant integrals, there are Delco Electric Motors to fit your products and meet your industrial needs. Every one is built to rigid standards of quality, and subjected to rigorous tests throughout production.

Delco Electric Motor parts and service are available to your customers everywhere.

GM GENERAL MOTORS DELCO DAYTON OHIO

DELCO *Electric* MOTORS

DELCO PRODUCTS, DIVISION OF GENERAL MOTORS, DAYTON, OHIO

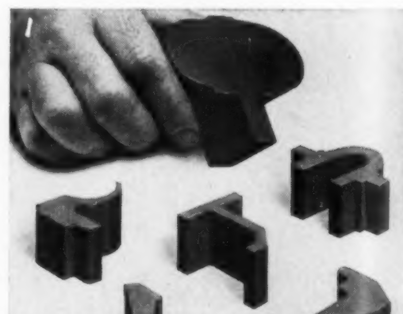
Proved best by Performance!

News Roundup

(*Continued from Page 45*)

and informing—were outlined by Dr. John T. Rettaliata, president of Illinois Institute of Technology, at the 84th anniversary of the American Institute of Mining and Metallurgical Engineers. Noting that engineers are moving into the field of management, he cited figures showing that 40 per cent of industrial management is engineer-trained. Engineers of the future will require more education in many fields beyond their professional specialties.

Complex carbon-steel steel shapes as well as other steels that cannot be rolled, are now being turned out at Jones & Laughlin Steel Corporation's new \$1,260,000 hot extrusion plant. Extrusions will



be available custom made because of the low cost of small-quantity production. To be produced at first in solid sections, the extrusions are made by the Ugine-Sejournet process.

Meetings

AND EXPOSITIONS

May 16-20—

Materials Handling Exposition to be held at the International Amphitheater, Chicago, Ill. Details are

available from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

May 23-24—
American Institute of Electrical Engineers. Sixth annual appliance technical conference to be held at Hotel Hollenden, Cleveland, O. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

May 23-25—
American Society for Quality Control. Annual meeting and exhibit to be held at the Statler Hotel, New York. Additional information may be obtained from society headquarters, 50 Church St., New York 7, N. Y.

May 23-25—
American Foundrymen's Society. Annual meeting to be held at the Rice - Shamrock Hotel, Houston, Texas. Additional information may be obtained from society headquarters, 616 South Michigan Ave., Chicago 5, Ill.

May 30-June 10—
Canadian International Trade Fair to be held at Exhibition Park, Toronto, Ontario, Canada.

June 2-4—
National Society of Professional Engineers. Annual meeting to be held at the Bellevue-Stratford Hotel, Philadelphia, Pa. Additional information may be obtained from society headquarters, 1121 15th St. N. W., Washington 5, D. C.

June 5-8—
American Gear Manufacturers Association. Annual meeting to be held at The Homestead, Hot Springs, Va. Additional information may be obtained from society headquarters, One Thomas Circle, Washington, D. C.

June 6-9—
American Society of Mechanical Engineers. Twenty-seventh annual conference and exhibit of the Oil

and Gas Power Division to be held at Hotel Statler, Washington, D. C. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

June 7-10—
American Welding Society. National spring meeting and exposition to be held at the Municipal Auditorium, Kansas City, Mo. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

June 12-15—
American Society of Agricultural Engineers. Annual meeting to be held at the University of Illinois, Urbana, Ill. Secretary is Frank B. Lanham, Saint Joseph, Mich.

June 12-17—
Society of Automotive Engineers. Summer meeting to be held at the Chalfonte-Haddon Hall, Atlantic City, N. J. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

June 14-16—
First Magnetics Conference and Exhibit to be held at the William Penn Hotel, Pittsburgh, Pa., under the auspices of the American Institute of Electrical Engineers in cooperation with the American Physical Society and the American Institute of Mining & Metallurgical Engineers. Additional information may be obtained from A. C. Beiler, c/o Westinghouse Electric Corp., 2-F Materials Engineering Dept., East Pittsburgh, Pa.

June 16-18—
Malleable Founders' Society. Annual meeting to be held at The Greenbrier, White Sulphur Springs, W. Va. Additional information may be obtained from society headquarters, Union Commerce Bldg., Cleveland, O.

June 19-23—
American Society of Mechanical Engineers. Diamond Jubilee Semi-Annual Meeting to be held at Hotel Statler, Boston, Mass. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

June 20-23—
American Electroplaters' Society. Forty-second annual convention and Industrial Finishing Exposition to be held at the Public Auditorium, Cleveland, O. Exposition managers are Harold E. Bartlett and Albert W. Erickson, American Decorating Co., 1849 West 24th St., Cleveland 13, O.

June 21-24—
Institute of the Aeronautical Sciences. Fifth International Aeronautical Conference to be held at the IAS Bldg., Los Angeles, Calif. Additional information may be obtained from society headquarters, 2 East 64th St., New York 21, N. Y.

June 27-July 1—
American Institute of Electrical Engineers. Summer General Meeting to be held at New Ocean House, Swampscott, Mass. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

June 26-July 1—
American Society for Testing Materials. Annual meeting to be held at the Chalfonte-Haddon Hall, Atlantic City, N. J. Executive secretary is R. J. Painter, 1916 Race St., Philadelphia 3, Pa.

July 12-14—
Western Plant Maintenance & Engineering Show to be held at the Pan Pacific Auditorium, Los Angeles, Calif. Additional information may be obtained from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

August 24-26—
Western Electronic Show and Convention to be held at the Civic Auditorium, San Francisco, Calif. Additional information may be obtained from Mal Mobley Jr., Business Manager, 344 North La Brea Ave., Los Angeles 36, Calif.

MEN

OF MACHINES

Formerly chief engineer, **Kurt O. Tech** has been named vice president in charge of engineering by Cross Co., Detroit. Mr. Tech, who

Kurt O. Tech

headed the company's engineering department for nine years, is a member of the Society of Automotive Engineers, the American Institute of Electrical Engineers, the American Ordnance Association and the Engineering Society of Detroit.

William H. Graves has been elected vice president and director of engineering of the Studebaker-Packard Corp. for both lines of automobiles. He has been associated with Packard since 1919 and head of engineering since 1950. **Herbert L. Misch** replaces Mr. Graves as chief engineer of the Packard division.

Roy H. Olson has been appointed director of engineering in the Communications and Electronics Div. of Motorola Inc., Chicago. He will direct technical activity of the division's industrial products department. A veteran of 20 years in the radio industry, Mr. Olson was associated with Collins Radio Co. for 13 years, then operated his own manufacturing and consulting firm before joining Motorola.

Rudolph F. Onsrud, president of Onsrud Machine Works, Chicago, and Onsrud Cutter Mfg. Co., Libertyville, Ill., has been elected a Fellow of the American Society of Mechanical Engineers.

Allen Electric and Equipment Co., Kalamazoo, Mich., has appointed **Byron Campbell** vice president and director of engineering. He will head the company's engineering, design and development staff. Mr. Campbell holds a B. S. degree in electrical engineering from Case Institute of Technology. He also did post graduate work at Johns Hopkins University. Following graduation he joined the Timken Roller Bearing Co. as development

Byron Campbell

Men of Machines

engineer in charge of engine and physical laboratories. Subsequently he was affiliated with the Glenn L. Martin Co., Baltimore, and Harry Ferguson Inc., Detroit. An active member of the Society of Automotive Engineers, Mr. Campbell has served as a member or chairman of several committees. He is also a member of the American Society for Testing Materials and the American Society for Metals.

Joseph I. Bosi was recently appointed chief engineer by Hydro-Line Mfg. Co., Rockford, Ill. He joined the company in 1950 as an engineer-draftsman.

A. M. Davis has joined the power plants division of Marquardt Aircraft Co., Van Nuys, Calif., as chief of engineering and manufacturing services. Previously he was chief production engineer of A. V. Roe Canada, Ltd.

Wisconsin Motor Corp., Milwaukee, has appointed **F. B. Esty** chief engineer and **Ralph Switzer** director of research and development engineering. Mr. Esty has been assistant chief engineer since joining the company in 1948. He has been active in the Internal Combustion Engine Institute and has served on committees guiding the Engine Standardization Program of the Department of Defense. Mr. Switzer has been associated with

F. B. Esty

Ralph Switzer

Wisconsin Motor since 1928. An active member of the Society of Automotive Engineers, he is chairman of the Milwaukee section.

M. Eugene Merchant recently was awarded the Sixth Annual Outstanding Engineer Award by the Technical and Scientific Societies Council of Cincinnati. Dr. Merchant is assistant director of research of Cincinnati Milling Machine Co.

Two promotions in the engineering section at AC Spark Plug Div. of General Motors Corp. at Flint, Mich., are those of **Wilfred A. Bychinsky** to assistant chief engineer of a newly created Motor Group and **Alfred Candelise** to experimental engineer in charge of spark plugs.

Schwitzer-Cummins Co., Indianapolis, has announced the appointment of **James A. Hardy** to the position of executive engineer and **Thomas J. Weir** to assistant chief engineer.

Vice president in charge of engineering since 1951, **William H. Harris Jr.** has been named vice president and assistant general manager of Micromatic Hone Corp., Detroit. Mr. Harris joined the company in 1935.

Micromatic also has appointed **R. G. Ellis** chief engineer. Asso-

ciated with the company since 1939, he was named assistant chief engineer last year.

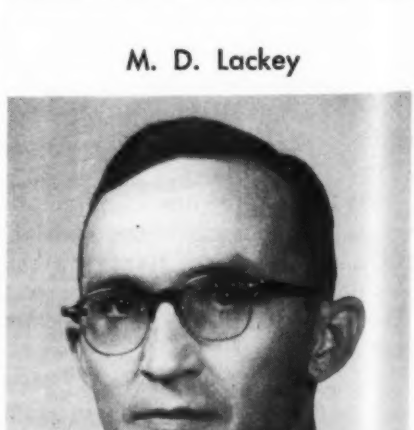
Link Aviation Inc., Binghamton, N. Y., recently annnounced the promotion of **Laurence E. Fogarty** to chief engineer and **John M. Hunt** to director of research and development. Other promotions include those of **Robert F. Hall** to manager of manufacturing engineering, **Vincent S. Kraeger** to manager of administrative engineering, **Milton S. Wade** to manager of standardization and **Melvain Oliphant** to project manager for a simulator and a trainer project.

Martin H. Olstad has been elected to the newly created position of vice president in charge of engineering of Niagara Blower Co., New York. He joined the company in 1929 and for the last ten years has been chief engineer.

Formerly chief of the Navy Bureau of Ships, Rear Admiral **Wilson D. Leggett Jr.**, USN (Ret.), has joined American Locomotive Co. as vice president of engineering.

M. D. Lackey has been named chief product engineer by Unit Rig & Equipment Co., Tulsa, Okla. Mr. Lackey received a B.S. degree in mechanical engineering from Oklahoma A and M in 1941. Prior

M. D. Lackey



to joining Unit Rig's engineering department in 1952 as a design engineer, he was associated with Bethlehem Supply Co., Westinghouse Electric Co. and the Oil Well Supply Div. of U. S. Steel Corp.

James Adams Jr. who has been engaged in research and development work at Raybestos-Manhattan Inc., New York, since 1939, has been named chief engineer of research and product design of the Manhattan Rubber Div.

The Boston Works of Allis-Chalmers Mfg. Co. has promoted **H. L. Peek** to engineer in charge of the development group, **W. L. Vance** to engineer in charge of circuit breaker design and **J. F. Claffie** to section engineer for high-voltage outdoor breakers.

Edwin E. Parker has been appointed general manager of the Instrument Department of General Electric Co. at Lynn, Mass. Mr. Parker joined the company in 1931 as a student engineer and served in several engineering capacities, including manager of the Research Application Services Department of the Research Laboratory, the position he had held since October 1953.

Warren H. Brand has been elected vice president in charge of engineering and research of Conoflow Corp., Philadelphia. He joined the company in May of last year as director of engineering and research.

Formerly chief engineer, **Raymond E. Dewey** has been named manager of operations by Ohio Seamless Tube Div. of Copperweld Steel Co., Shelby, O.

Alexander H. Kuhnel has been named assistant manager of the Special Devices Div. of the Austin Co., Cleveland. He will continue to serve in the capacity of division engineer.

Formerly director of research, **Paul A. Grobey** has been appointed director of engineering and research by Bryant Chucking Grinder Co., Springfield, Vt.

Job Security

A SYMPTOM of the human longing for safety in an uncertain world is the current preoccupation with security—of the nation and of the individual. It is natural and desirable to plan with all possible hazards in mind.

On an increasing scale government and industry are providing individuals with a measure of security against old age, sickness and other hazards. Unemployment compensation and the guaranteed annual wage represent a reaching out for security against one of the greatest fears of all—a man's fear of losing his livelihood.

Engineers, no less than other industrially employed people, benefit or suffer from the economic ups and downs of a particular company or industry. When stiff competition, declining markets, or maybe just poor management force a company to cut back its engineering force, some engineers inevitably face a major crisis, even under today's conditions of heavy demand for engineers.

They are the ones whose horizons are limited by the requirements of the job at hand. They do only what is expected of them, perhaps they play company politics, they satisfy their employers after a fashion and they enjoy a measure of security so long as they remain tied to his apron strings.

What happens to that security if they are laid off, perhaps for good, or if changing conditions make a move desirable? What values can they offer a prospective new employer? If their activities and interests have indeed been confined to the demands of a specific job and a specific employer, and they have shown no initiative in personal and professional development, then their chances of fitting equally well into another job are at best uncertain. Their security is gone.

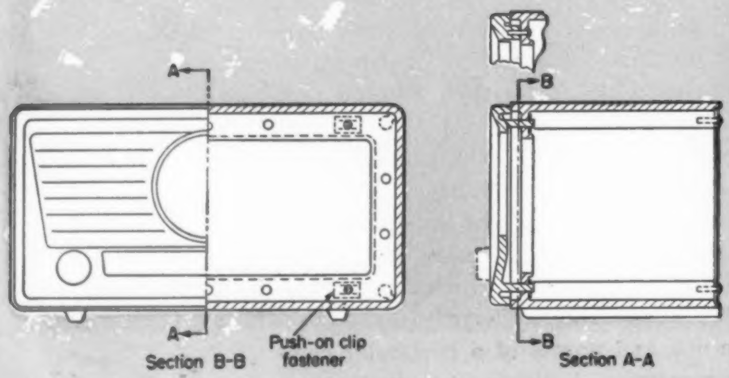
But other engineers have maintained their technical skill and knowledge of the engineering field. They have also kept abreast of latest developments over a broad area through professional society and other contacts and through reading engineering journals. They are the ones who still have security; their services will always be in demand.

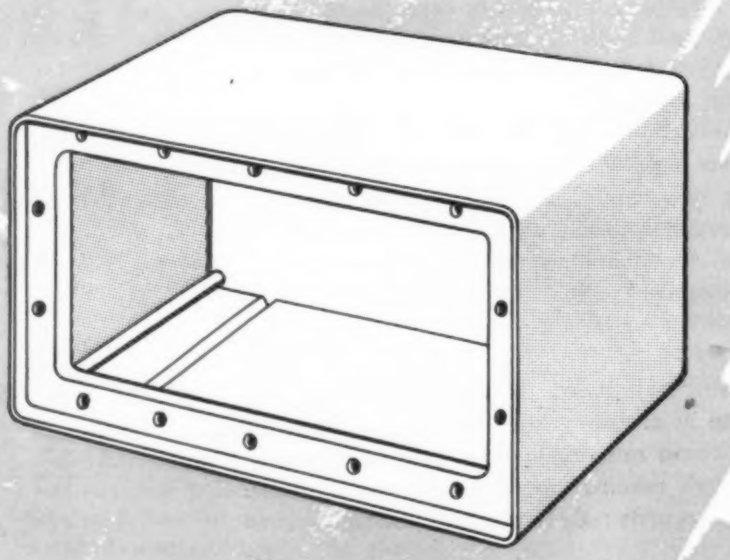
Colin Carmichael

EDITOR

INTERCHANGEABLE

By J. M. Little,
S.I.D., Industrial Designer
J. M. Little and Associates, Toledo, Ohio





HERE'S how to get variety in styling on a limited tooling budget. The method proposed in this article involves use of the same basic body housing plus a number of different fronts and mounting arrangements. The idea is not new, having been used by auto manufacturers for years. But it hasn't often been tried by manufacturers of smaller units—and it does deserve some attention as a useful and practical method.

Styling variations and approximate cost studies have been worked out for standard radio and clock-radio housings. However, the idea may also be practical for TV cabinets, clock cases, timing devices, electric meters, interoffice communication systems—almost any application where the basic body shell can be the same for a number of different models, but styling or function dictate the use of different faces.

Designs shown were worked out for Henry W. DeVore, Barrett Div., Allied Chemical and Dye Corp., using Plaskon urea resins for the body shell.

Basic housing is an open-face, open-back shell, molded in urea plastic. This thermosetting plastic permits widest latitude in color selection and, along with other thermosets, a hard, durable nonelectrostatic surface plus inherent rigidity. Mounting holes are molded into an inside flange on the basic shell. Enough are provided so that the face can be attached at different points for different dial or speaker-opening arrangements. The face, if molded of a thermoplastic material, can be attached by molded-in studs which are gripped after assembly by push-on fasteners. Or if a wood face is used, conventional screws and washers can be employed; if metal, self-tapping screws, etc. Self-tapping screws could also be used in attaching a fabric-covered, pressed-fiber front.

E STYLING

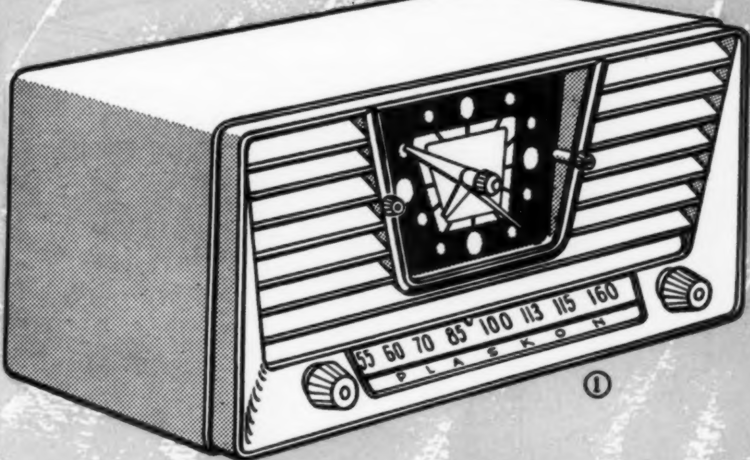
How a basic molded plastic shell can be combined with a variety of front faces to attain flexibility in appearance

Any holes necessary for side or top knobs or mounting arrangements can be drilled. Back is a conventional cardboard backing, although in other types of units the back could be molded separately or integral. Size of the shell arbitrarily selected for purposes of comparison is $9\frac{3}{4}$ inches wide by $5\frac{1}{4}$ inches high by $5\frac{1}{4}$ inches deep.

Front shown is molded plastic, offset from the main housing so that any inaccuracy or mismatching during assembly will not be noticeable. Materials such as wood, painted steel stampings, anodized aluminum stampings, chrome-plated die castings or countless others, are perfectly feasible. Fronts shown in the drawings are approximately 1 inch deep, including studs.

Advantage of the design concept, of course, is that tooling for the housing shell, which requires a deep-cavity die, can be amortized over a large number of pieces. Mold for the rectangular body shell, with its flat, uncomplicated surfaces, would last almost "forever"; actual experience with similar radio-cabinet moldings shows that mold wear is negligible over millions of pieces. On the other hand, molds or dies for the faces would be shallow and relatively inexpensive to build.

Four different front stylings, plus one mounting variation, illustrate the wide range of design possibilities and appearance effects. Style 1 is an injection-molded plastic front in moderate-impact polystyrene with molded-in louvers. A perforated-metal grille is the feature of style 2, with a molded moderate-impact polystyrene face. Style 3 has a cloth grille, again with a polystyrene front. Five variations have been worked out for style 4. A cloth grille is used in all, but the front edging can be a vinyl-coated steel stamping (integral color), finished wood, a chrome-plated die cast-



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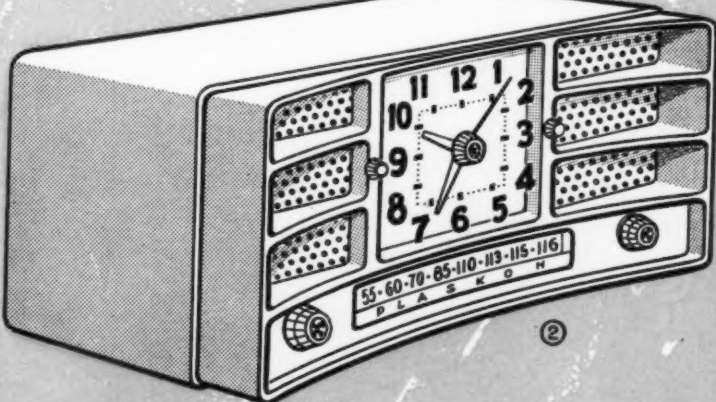

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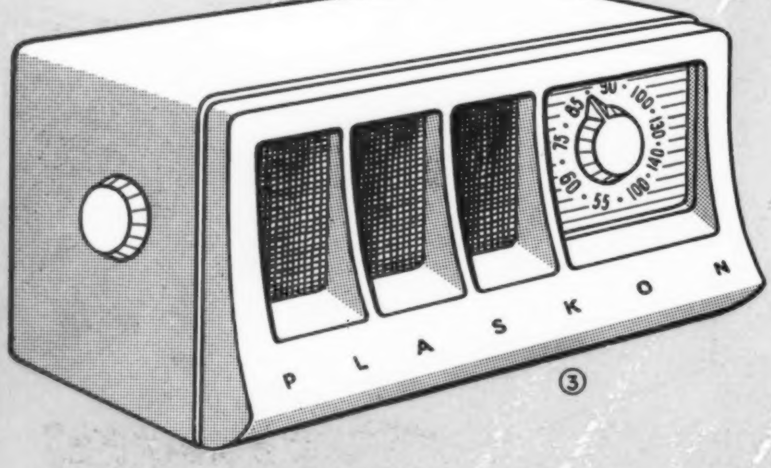
ing, an anodized aluminum stamping, or a lacquered aluminum stamping. On style 4, a wrought iron (or simulated wrought iron) mounting stand could be used, although other variations are possible. With all of the plastic fronts, two-tone color combinations are perfectly feasible.

Tooling costs for eight different stylings, as previously described, are compared here with the cost of tooling for eight single-cavity dies for one-piece plastic clock-radio housings. By contrast, mold cost for the basic housing shell is based on a two-cavity mold having inherently higher productivity. For the plastic fronts, molds can either be single or double-cavity, depending on quantity level; costs for both are shown.

Aproximate production costs for each style show about an "even break" in costs between one-piece and two-piece housings. But amortization of the basic back mold (or complete mold for one-piece housings) can have an effect on cost levels.

This amortization cost may be negligible if amortization is over a sufficiently large number of pieces. For instance, if the body shell die were amortized over 1 million pieces, mold amortization would add less than $0.01 per piece; if over 100,000 pieces, about $0.09 per piece.

The same body shell mold for the two-piece housing would presumably be used for a number of dif-



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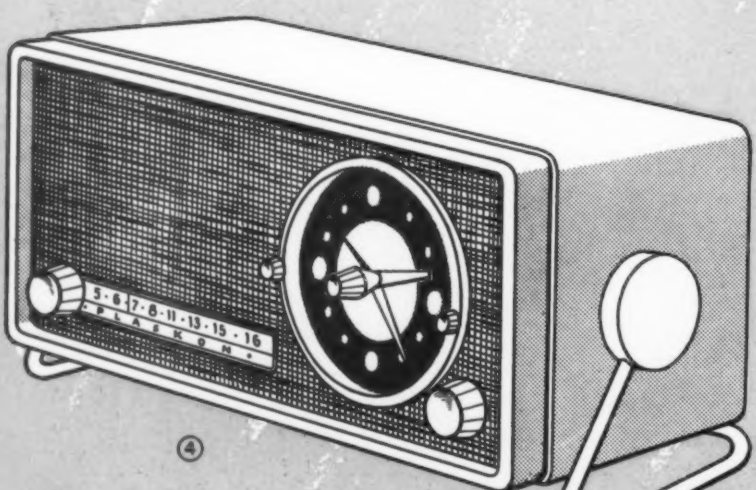

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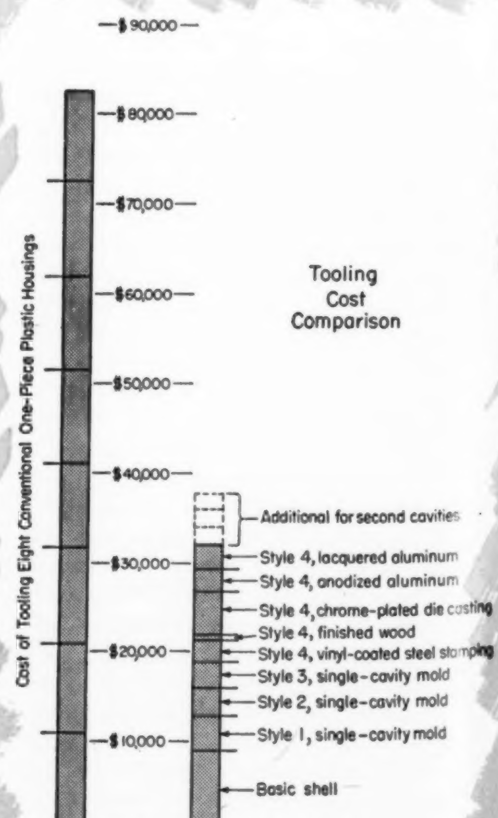


Comparison of Approximate Costs

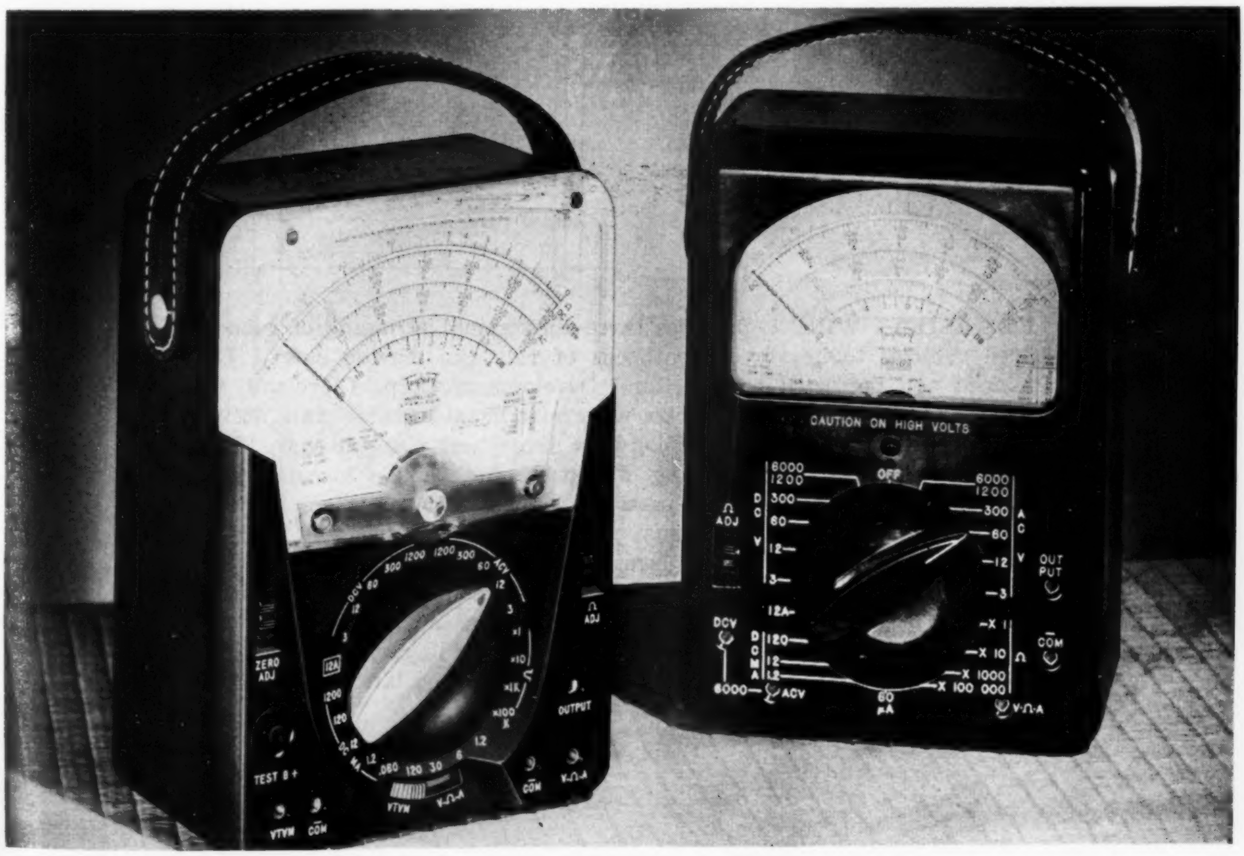
Style	Back Shell* Amortized Mold Cost† ($/piece)	Back Shell* Production Cost ($/piece)	Front Type	Front No. of Cavities	Front Tool Cost ($)	Front Amortized Tool Cost‡ ($/piece)	Front Production Cost ($/piece)	Grille Type	Grille Cost ($/unit)	Assembly Cost ($/unit)	Total Cost ($/unit)
1	0.009	0.96	Moderate-impact polystyrene	2	6000	0.06	0.33	Integral louvers	...	0.05	1.41
1	0.009	0.96	Moderate-impact polystyrene	1	4000	0.04	0.39	Integral louvers	...	0.05	1.45
2	0.009	0.96	Moderate-impact polystyrene	2	5000	0.05	0.34	Perforated metal	0.09	0.05	1.50
2	0.009	0.96	Moderate-impact polystyrene	1	3000	0.03	0.40	Perforated metal	0.09	0.05	1.54
3	0.009	0.96	Moderate-impact polystyrene	2	4700	0.047	0.30	Cloth	0.03	0.05	1.40
3	0.009	0.96	Moderate-impact polystyrene	1	3000	0.03	0.36	Cloth	0.03	0.05	1.44
4	0.009	0.96	Vinyl-coated steel stamping	..	2600	0.026	0.12	Cloth	0.03	0.05	1.20
4	0.009	0.96	Finished wood	..	200	...	0.52	Cloth	0.03	0.05	1.57
4	0.009	0.96	Chrome-plated die casting	..	5000	0.05	0.55	Cloth	0.03	0.05	1.65
4	0.009	0.96	Anodized aluminum stamping	..	2600	0.026	0.40	Cloth	0.03	0.05	1.48
4	0.009	0.96	Lacquered aluminum stamping	..	2600	0.026	0.67	Cloth	0.03	0.05	1.75
One-piece	0.105	1.40	Integral	..	....	...	...	Integral louvers	...	...	1.50

*Complete housing in the case of one-piece housings.
†Over 1 million pieces for styles 1 to 4; over 100,000 pieces for one-piece housing. Double-cavity mold for back shells; single cavity for one-piece housings.
‡Over 100,000 pieces.

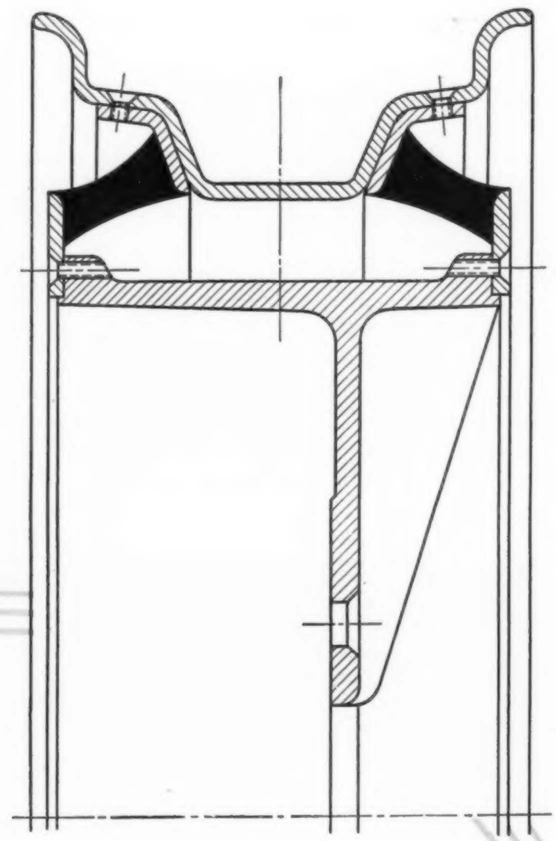
ferent models over a span of years. So volume levels could (depending, of course, on product) range up to 1 million pieces—or even more. This 1 million figure has been used in amortizing body shell mold costs.

Limiting criterion on the one-piece housing, however, is likely to be the styling, or model obsolescence. So amortization over a lower volume level is very realistic. For comparative purposes, amortization of the one-piece housing mold costs over 100,000 pieces adds about $0.10 to the cost per piece, the figure which has been used in the table. These factors, which have been accented in the table by choice of the amortization procedure, can easily be recalculated for other volume levels.

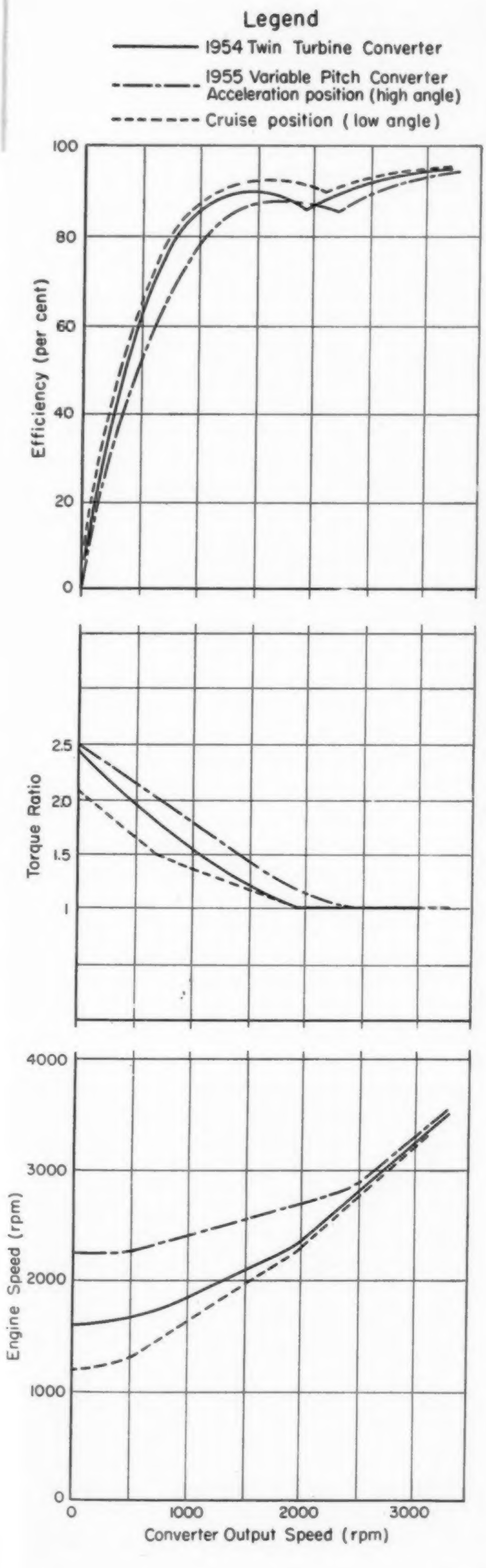
Actual application of this design concept is exemplified by instruments manufactured by Triplett Electrical Instrument Co. The same rear case is used on the newly styled combination volt-ohm-milammeter and vacuum-tube voltmeter, left, as on the earlier volt-ohm-mil-ammeter, right. A solid-back case is used, with through-holes molded-in to provide screwdriver access to fasteners for the front. The clear methacrylate window on the combination meter is a separate molding. The complete housing consists of three pieces—back case, front, and window.

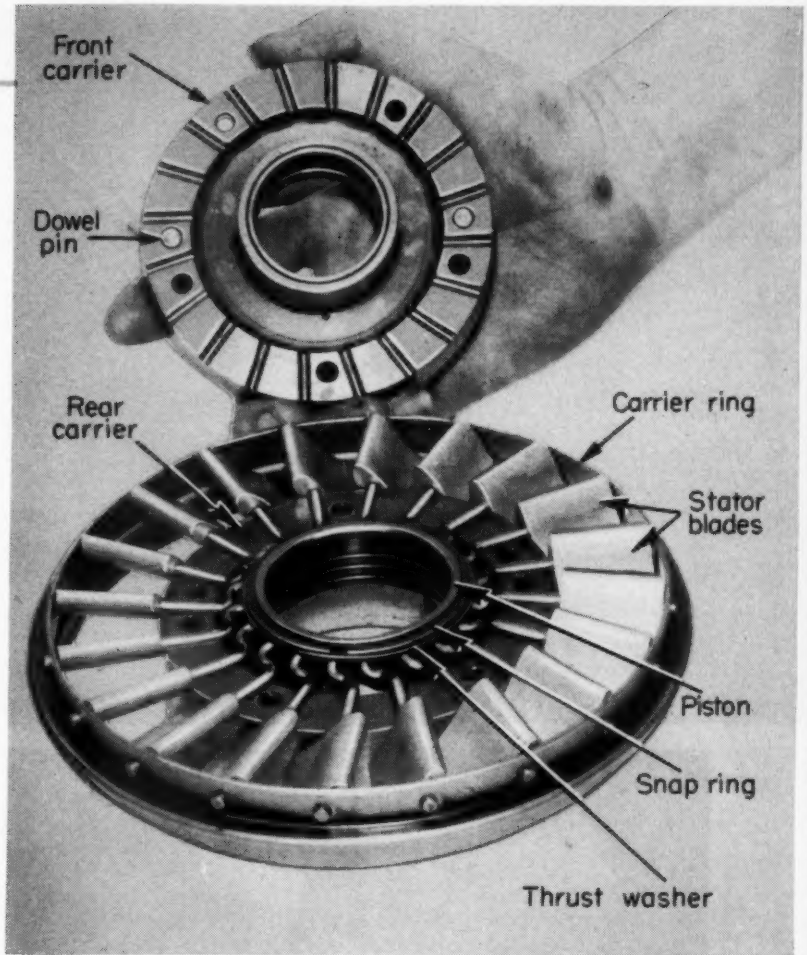


scanning the field for Ideas

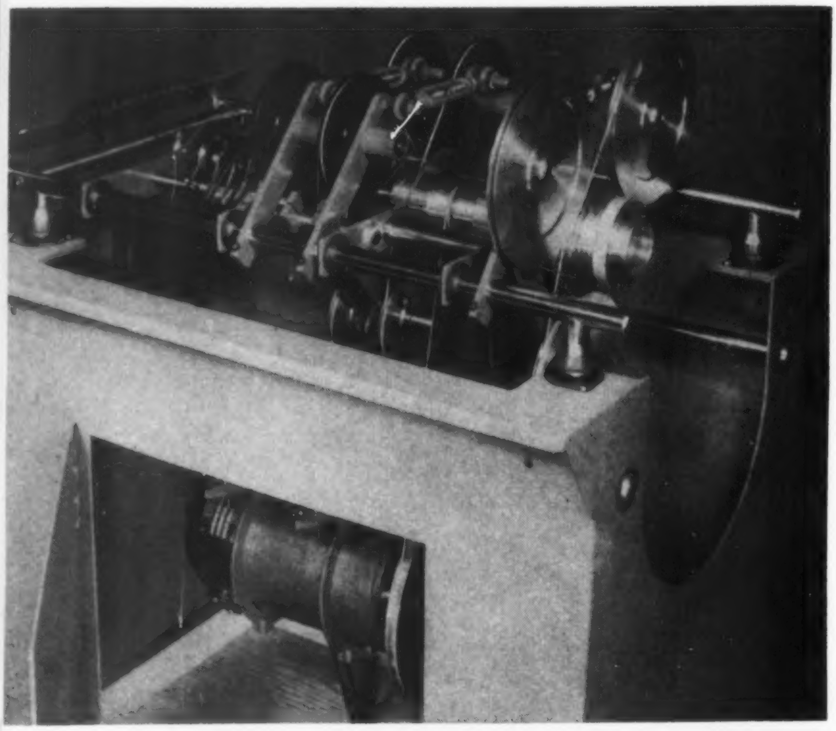


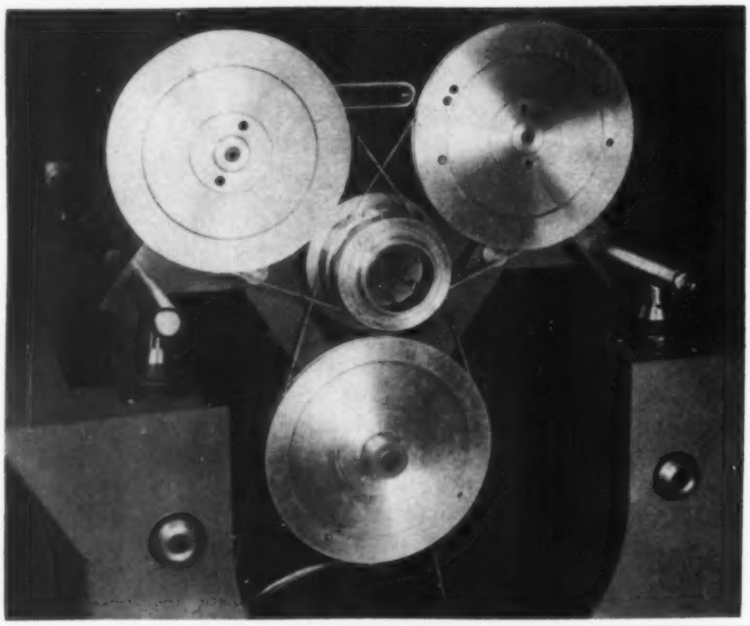
RESILIENT WHEEL provides three-dimensional springing of rubber-tired vehicles to improve smoothness of ride and driving safety. Developed and perfected by the Rand Development Corp., Cleveland, O., in conjunction with Goetzewerke, a German manufacturer, this design incorporates rubber "springs" between the wheel rim and hub. This technique reduces the unsprung weight of the vehicle essentially to just the tire, tube, and rim parts. The Rand-Goetze wheel includes two annular rubber diaphragms each vulcanized between a pair of steel rings. These assemblies are fastened to the rim of the wheel and to the hub with the rubber stressed in tension so the wheel will not become unstable. Vehicle acceleration and deceleration are said to be improved since the wheel can wind up in torsion. Also, the wheel can absorb side shock as it possesses lateral flexibility.





VARIABLE-PITCH stator blades in Buick Dynaflow transmission permit faster acceleration and improved fuel economy. This fluid torque converter operates on the same principle as employed in variable-pitch propellers and hydraulic turbines. The driver can change the angle of the vanes in the stator to a high pitch for fast acceleration, either from a standing start or at any road speed for passing by pressing the accelerator to the floor. This action initiates movement of a hydraulic piston which rotates the stator blades to a high pitch angle. Higher torque output at high pitch angle results from twofold action: torque multiplication ratio increases and the engine "revs up" to its maximum torque speed. At low pitch angle the efficiency is higher, and the lower torque ratio permits the engine to run slower, resulting in improved fuel economy.



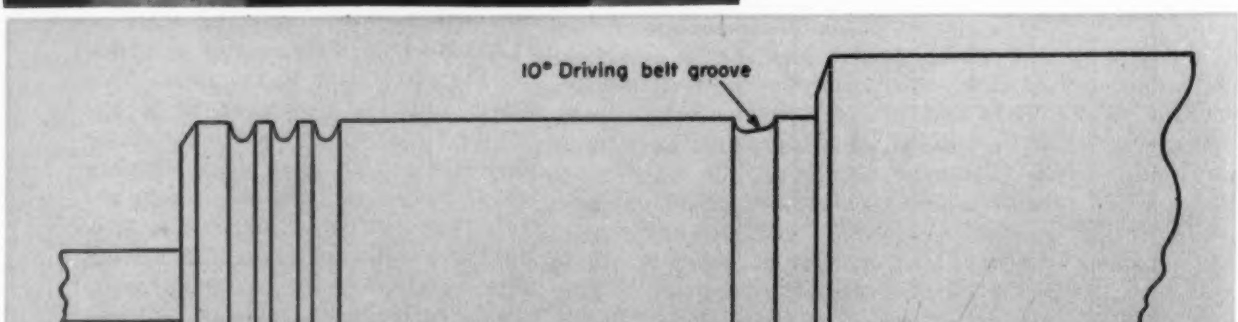


ULTRAHIGH ROTATIONAL SPEEDS in a centrifuge are made possible by use of a novel tribelt suspension technique. Eastman Kodak's Navy Ordnance Div. is employing this design approach to solve the rotor mounting and bearing problems in a device for testing spinners, some of which are being designed to operate at speeds up to 84,000 rpm.

Belts are 1/16-inch diameter woven nylon, spliced to appear endless. Each has a tensile strength of 260 pounds, giving ample ratio of rotor weight to belt strength. In one particular test these nylon belts had a normal life of about three weeks when used for intermittent operation at 600 rps.

Ends of the rotor in the spinner are supported by these belts from 6-inch diameter ball-bearing idler pulleys mounted 120 degrees apart. These pulleys are individually adjustable to align the rotor and allow for belt length tolerance.

The rotor in this unit is belt driven by a 3-hp universal motor with a top speed of 18,000. This speed is stepped up 4 to 1 through pulleys. To prevent slippage on the rotor or motor pulley a novel complete wrap-around of the belt is used. To minimize belt wear, a 10-degree angle of inclination is introduced to both the rotor groove and the motor pulley groove. The angle of inclination on one groove is opposite to the other, causing the driving belt to enter on the high side of the angle of either groove and leave on the low side.



When to use

Vacuum-Formed Plastics

Basic factors in vacuum forming of sheet-plastic parts

By Carl H. Bagen
Technical Representative
Kaye-Tex Mfg. Corp.
Yardville, N. J.

ALTHOUGH millions of pounds of plastic material are vacuum-molded annually, the process is relatively new and still passing through the art stage which generally precedes the science. Nevertheless, it is now possible for designers to make use of this rapidly growing process for many plastic components.

The intention here is to define what can be done in general terms, rather than how it can be done.

Vacuum-Forming Process: Vacuum forming is a method of employing partial atmospheric pressure to force a hot, flexible thermoplastic sheet into conformity with a mold. Present-day vacuum-forming machines are designed to operate over a wide range of mold depths and areas, as well as to incorporate varying degrees of automatic cycling with precise control of cycle, heat, evacuation rate, etc. Basic method and sequence of the cycle are shown in *Fig.* 1.

Possibilities for variation in the basic process are broad, and a great many variations actually do exist, each with unique considerations of cycle, heat, evacuation rate, drape rates, heat-distribution assists, and mold capacity in both area and depth.

Materials for Vacuum Forming: The process is generally confined to the thermoplastic group of materials in sheet form, that is, those which soften on heating and return to their original condition of rigidity on cooling. There are many members of this group, and most have been successfully formed at one time or another. The group includes the flexible and rigid vinyls, the range of styrene copolymers, the polyethylenes, cellulose acetate and cellulose acetate butyrate, etc.

Choice of the correct plastic material for a particular molding is, of course, a function of many variables. These would include such considerations as decorative effect, strength, impact resistance, rigidity and, of course, economics.

The designer of a vacuum-molded part has available an almost unlimited range of color, as well as opacity from crystal clear to opaque. In addition, surface decorative effects such as prints and embossings are available. Rigidity ranges from the very soft, flexible vinyls to hard, rigid materials, and impact strength from below 1 to over 10 ft-lb per inch of notch, Izod.

Resulting Part: The basic product produced by vacuum forming is the open box. The "box" can range from a few thousandths of an inch in height, as in flexible vinyl place-mat embossing where the mold is a decorative pattern of surface irregularities, up to boxes a foot or more deep. Area of the box can vary from a fraction of an inch up to several square feet. Small parts are generally molded on multiple-cavity, or multiple-plug, molds.

To a large extent, depth of the box to be produced dictates the choice between straight vacuum drawing or the vacuum drape method. Generally, for shallow draws ranging from a few thousandths of an inch in depth to approximately 1 to 2 inches in depth, the plastic sheet is held in a fixed retaining frame and drawn into the mold cavity, which contains either a male or a female, single

or multiple mold. For greater depth, the drape method is the preferred system. However, there is no fixed rule of choice.

On deep draws with the drape method, only the male mold is used. However, on shallow draws either a cavity or plug mold can be used with the choice contingent on the particular product.

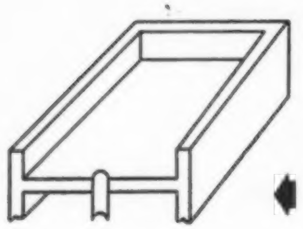
To say that the basic product is "box-like" is perhaps an oversimplification, for actually the drawn product can be of almost unlimited contour, while still maintaining the box-like structure. *Fig.* 2 illustrates a feasible vacuum-formed structure. Note that while the structure has molded indents, rises, flanges, square and round sections, it is nevertheless basically an open (at the bottom) box.

Typical Component Design: As an example of a feasible forming project, consider the part shown in *Fig.* 2. The first step in designing this component for molding by vacuum would be to consider the various thermoplastic sheet materials available in light of intended use requirements. Typical considerations might be:

The part must be rigid.
The part must withstand normal wear and tear. Therefore, impact strength should be moderately high.

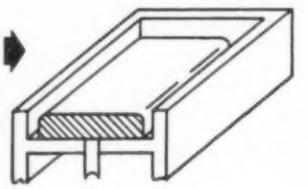
These requirements narrow the choice to the cellulosics and the styrene copolymers, among the common materials. Subsequent consideration would narrow this down, and for example, a styrene

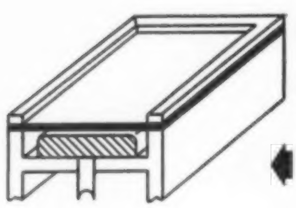
Vacuum Forming



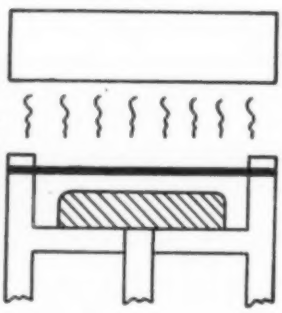
Mold cavity, generally variable in both depth and area, is adjusted to fit the particular job. The evacuation vent, or piping, is generally located to enter this cavity centrally

Mold cavity with mold in place. Provision must be made to facilitate rapid evacuation of the air in the cavity through the vent. This is done by drilling the mold with a series of fine holes and by supporting the mold over the main vent on a porous surface

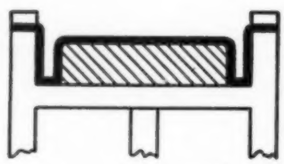




Plastic sheet in position and held down by a clamp, or retaining frame. This must make an airtight assembly to insure as high a differential pressure between the upper and lower surfaces of the plastic as possible



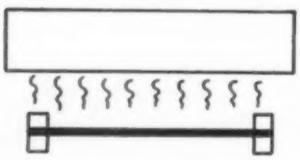
Movable radiant heater positioned so that the plastic sheeting, tightly held against distortion and air leakage, is heated to the optimum working temperature

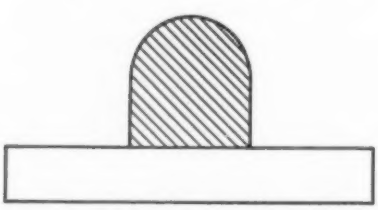


Molding which takes place upon evacuation of the air from the mold chamber. Atmospheric pressure is maintained for a short cooling cycle. Cycle time, from the insertion of the blank plastic sheet to removal of the part, varies from as low as 15 seconds to several minutes, with 30 to 40 seconds being typical

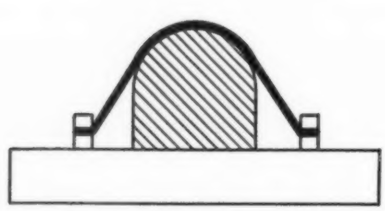
Fig. 1 — Steps in the vacuum forming process

Drape Technique

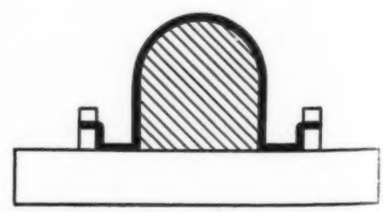




Recent development is the drape technique, in which the mold is placed on a table rather than in a cavity. The plastic is brought to temperature above the mold while held in a retaining frame capable of rapid, uniform vertical travel



Retaining frame descends to the table when the sheet has reached optimum temperature, forming an air-tight seal with the table and draping the hot, flexible, plastic sheet tent-like over the mold



Air is evacuated as soon as the retaining frame has descended to airtight contact with the table, and atmospheric pressure forces the sheet into conformity with the mold

copolymer of moderate impact strength could be chosen here.

The next step would be to design the part and prepare a prototype by vacuum forming. The basic design pointers given in *Fig.* 3 should help avoid some of the more commonly encountered difficulties in molding. And, since the process is still in its infancy, one of the best approaches is to have a relatively inexpensive wooden pattern made by a competent patternmaker, preferably by one experienced in this particular field.

Consideration of the proposed structure would indicate drape forming over a plug mold for this particular part. If the resultant wooden pattern is satisfactory, it may then be used (with care) to produce a few sample pieces in a range of plastic thicknesses.

The molding of these samples in a range of thicknesses will indicate to the vacuum former those cycle and manipulation techniques he will have to adopt to produce the part, and further, he will have some idea of the number of pieces he can efficiently produce on a single drape. After a few cycles, he will be in a position to estimate his cost reasonably closely.

The same sample molding, in a range of thicknesses, would indicate to the designer the reduction in plastic thickness caused by the drawing operation, which effectively increases the area of the original blank. On this point, some difficulty may arise.

Whenever any sheet plastic material is vacuum-drawn into a finished shape whose total area is substantially greater than the original blank, the wall thickness, naturally, will be less than the thickness of the original blank. Unfortunately, however, this thinning of the wall section is not uniform throughout all areas of the molded structure, giving rise to thin areas.

The molder can do much by his technique to relocate and minimize these thin areas, and the de-

Fig. 2—Possible part design, using indents, flanges, square and round sections

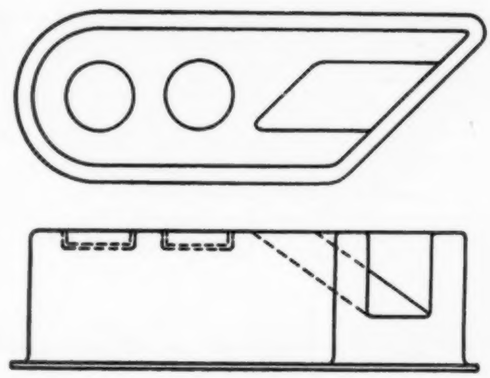
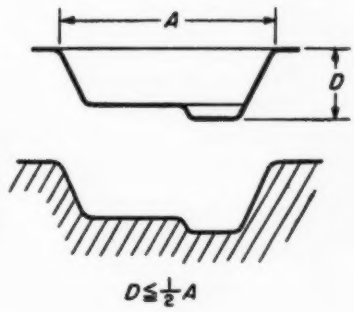
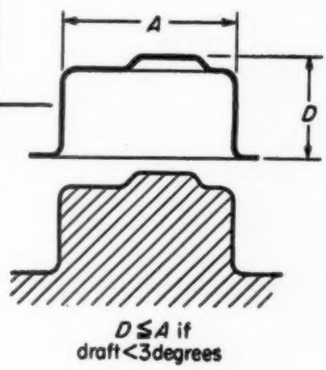


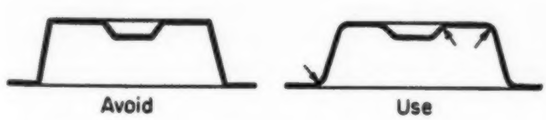
Fig. 3—Basic pointers on designing vacuum-formed plastic parts

Maximum draw depth for cavity molds cannot exceed one-half the span of the cavity

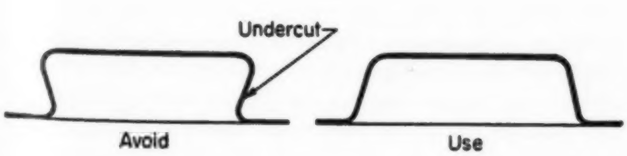


Maximum draw depth for drape molding over plugs with less than 3 degrees of draft should not exceed the span of the top of the plug



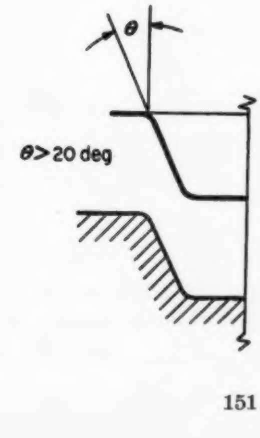


Radii or rounded edges should be used instead of sharp corners or edges



Slight undercuts and zero draft should be avoided, since they make release of the piece from the mold difficult. Definite undercuts can be handled (at higher cost) if split molds can be used to permit release of the part

Wall drafts less than 20 degrees for cavity molds cannot be successfully drawn



signer can help by specifying the use of a sufficiently thick blank section to insure strength and rigidity at the thin areas.

Actually, the designer can get some idea of the thinning before the drawing of the part by relating the total area of the part to the original area of the blank. This will indicate the resultant average thickness based on a uniform draw. Since the draw is something less than uniform, the thin areas will be somewhat under this average thickness. Reverse calculations based on the minimum allowable section will give a starting blank thickness.

Actually, after a little experience with this type of molding, the designer will be able to predict results fairly closely. Until that experience is gained, a sample molding over the wooden pattern will give a good deal of information.

Decisions have now been made regarding the drape process, the use of a plug mold, the type and thickness of plastic sheeting. After all of this is satisfactory, last-minute modifications can be made, such as any additional rigidifying indentations, final trimming, hole punching, etc. The resulting part can undergo further processing, such as drilling, cementing, hot stamping (of legends and designs), punching, riveting, sawing, sewing and shearing.

As mentioned before, merely an indication of what can be done has been given: it is up to the designer to exploit the many variations possible.

Removable Valve Parts Simplify Vacuum System Design

DESIGNED so that its handle and stem are readily removable, this high-vacuum seal-off valve is especially adaptable to small apparatus. Developed at the National Bureau of Standards, the valve may be used as a pressure seal or combination safety valve.

Vacuum systems are commonly sealed off either by installing a complete valve or pinching off annealed metal tubing. Pinching of the tubing requires the soldering or welding of a new piece into the system each time it is evacuated. This often presents difficult problems of manipulation.

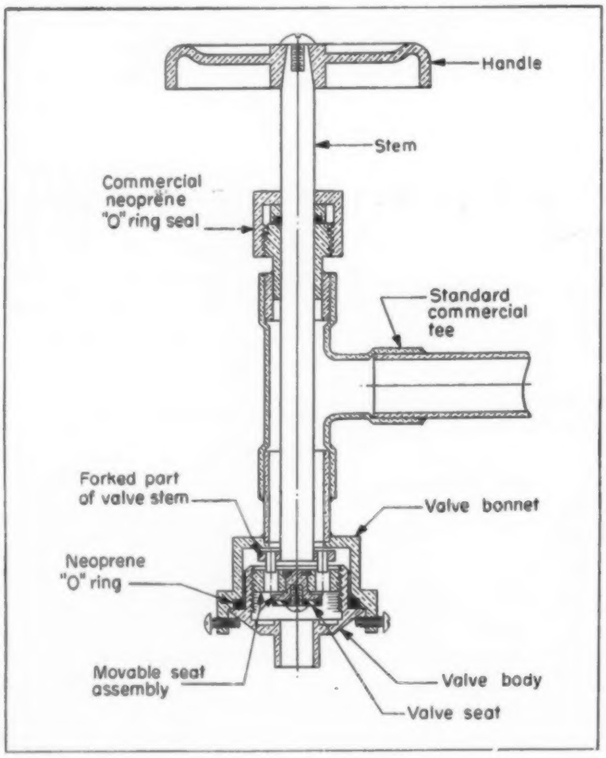


Fig. 1—Parts of the removable seal-off valve assembly. Bonnet screws, when tightened hold the entire movable assembly in place

A permanent pumping tap is provided by the NBS valve assembly. It can be used many times without soldering or welding. Principal parts, *Fig.* 1, are a valve handle and stem, valve body and seat, and a removable bonnet enclosing the seat assembly and adjacent end of the stem.

The movable seat contains six ports through which the vacuum system is pumped out. A narrow bar containing two small pins is attached to the end of the stem.

To operate the assembly, the pins are made to engage two of the ports in the seat. The valve handle is then turned to operate the valve. Screws in the bonnet hold the assembly in place.

After the system has been evacuated, the valve handle is turned to seat the valve, the bonnet screws are loosened and the seat assembly is removed as a unit.

Because of the very short ports in the valve, the valve body can be made very small without sacrificing pumping speed. The parts can be made of any suitable material, but a neoprene seat is recommended for use on high-vacuum systems.

"Research is a high-hat word that scares a lot of people. It needn't. It is rather simple. Essentially, it is nothing but a state of mind—a friendly, welcoming attitude toward change. Going out to look for a change instead of waiting for it to come. Research, for practical men, is an effort to do things better and not to be caught asleep at the switch. The research state of mind can apply to anything; personal affairs or any kind of business, big or little. It is the problem-solving mind as contrasted with the let-well-enough-alone mind. It is the composer mind instead of the fiddler mind. It is the 'tomorrow' mind instead of the 'yesterday' mind"—CHARLES F. KETTERING

Tolerances for Die Castings

New engineering standards set practical production limits for linear dimensions, draft, and flatness

ENGINEERING standards, aimed at setting practical tolerance levels for die-cast components, have recently been issued by the American Die Casting Institute. The standards, presented here, are for tolerances and drafts recommended by members of the Institute as representing normal production practice at the most economic level. Greater accuracy, involving work or extra care in production, can be specified, but may involve additional cost.

Linear Dimension Tolerances: As-cast tolerances for dimensions not affected by the parting line or by a moving die part are given in *Tables* 1 and 2. For example, an aluminum die casting with a critical dimension (*Table* 1) of 4.000 inches would have a tolerance of ±.0085-inch. Or a noncritical dimension of 13.00 inches (*Table* 2) on a zinc die-cast part should have a tolerance of ±.0275-inch.

Parting-Line Tolerances: When the parting line affects a linear dimension, tolerances from *Table* 3 must be added to those of *Tables* 1 or 2. An example would be an aluminum part with a critical dimension of 3.000 inches and a projected area at the die parting plane of 75 square inches. Tolerance would be: .004 + 2(.0015) = ±.007-inch (*Table* 1), plus ±.008-inch (*Table* 3), for a total tolerance of ±.015-inch.

Moving Die-Part Tolerances: Again, for dimensions affected by a moving die part, tolerances from Table 4 must be added to tolerances obtained from *Tables* 1 or 2. And if both a moving die part and the parting plane affect the dimension, all

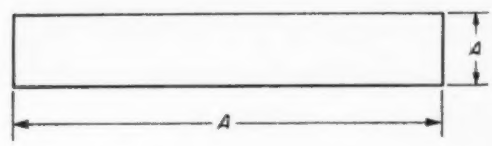


Table 1—Linear Dimension Tolerances, As Cast: Critical Dimensions*

Dimension *A*	Zinc (in.)	Aluminum (in.)	Magnesium (in.)	Copper (in.)
Basic Tolerance				
To 1 in.	±.003	±.004	±.004	±.007
Additional Tolerance, per inch				
Over 1 to 12 in.	±.001	±.0015	±.0015	±.002
Over 12 in.	±.001	±.001	±.001	.....

*Basic dimension in three-place decimals. Tolerances must be modified if a parting line or moving die part affects the dimension.

Table 2—Linear Dimension Tolerances, As Cast: Noncritical Dimensions*

Dimension *A*	Zinc (in.)	Aluminum (in.)	Magnesium (in.)	Copper (in.)
Basic Tolerance				
To 1 in.	±.010	±.010	±.010	±.014
Additional Tolerance, per inch				
Over 1 to 12 in.	±.0015	±.002	±.002	±.003
Over 12 in.	±.001	±.001	±.001	.....

*Basic dimension in two-place decimals or fractions. Tolerances must be modified if a parting line or moving die part affects the dimension.

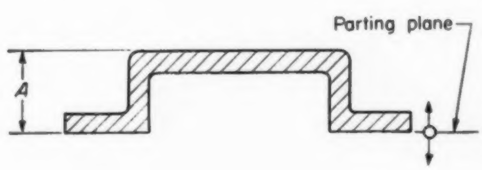


Table 3—Parting Line Tolerances*

Projected Area of Die Casting	Zinc (in.)	Aluminum (in.)	Magnesium (in.)	Copper (in.)
To 50 sq in.	±.004	±.005	±.005	±.005
50 to 100 sq in.	±.006	±.008	±.008	.....
100 to 200 sq in.	±.008	±.012	±.012	.....
200 to 300 sq in.	±.012	±.015	±.015	.....

*Add to linear dimension tolerances, *Tables* 1 or 2. Based on single-cavity die.

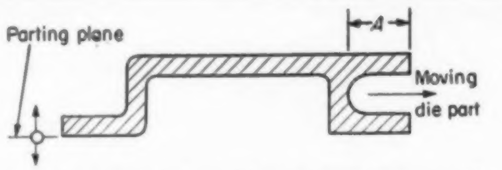


Table 4—Moving Die Part Tolerances*

Projected Area of Moving Die Element	Zinc (in.)	Aluminum (in.)	Magnesium (in.)	Copper (in.)
To 10 sq in.	±.004	±.005	±.005	±.010
10 to 20 sq in.	±.006	±.008	±.008	.....
20 to 50 sq in.	±.008	±.012	±.012	.....
50 to 100 sq in.	±.012	±.015	±.015	.....

*Add to linear dimension tolerances, *Tables* 1 or 2. Tolerances are in addition to those specified in *Table* 3 if dimension is also affected by parting plane.

Table 5—Flatness Tolerances

Longest Dimension*	Tolerance (in.)
Basic tolerance, to 3 in.	.008
Additional tolerance, per in.	.003

*Diameter of circular surface or diagonal of rectangular surface.

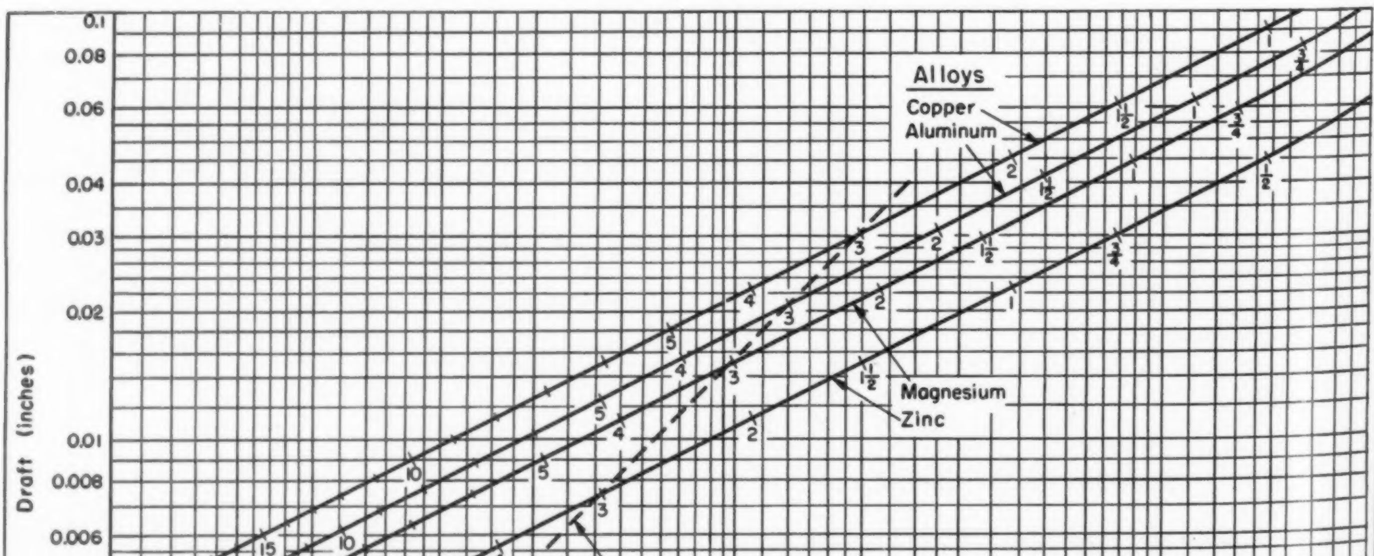
three tolerances must be added together (tolerances from *Table* 1 or 2, *Table* 3, and *Table* 4).

Flatness Tolerances: Flatness is measured with a feeler gage at three widely separated points on a continuous plane surface of the die casting. The "longest dimension" in *Table* 5 is the maximum dimension of the surface (i.e., diagonal of a rectangular surface).

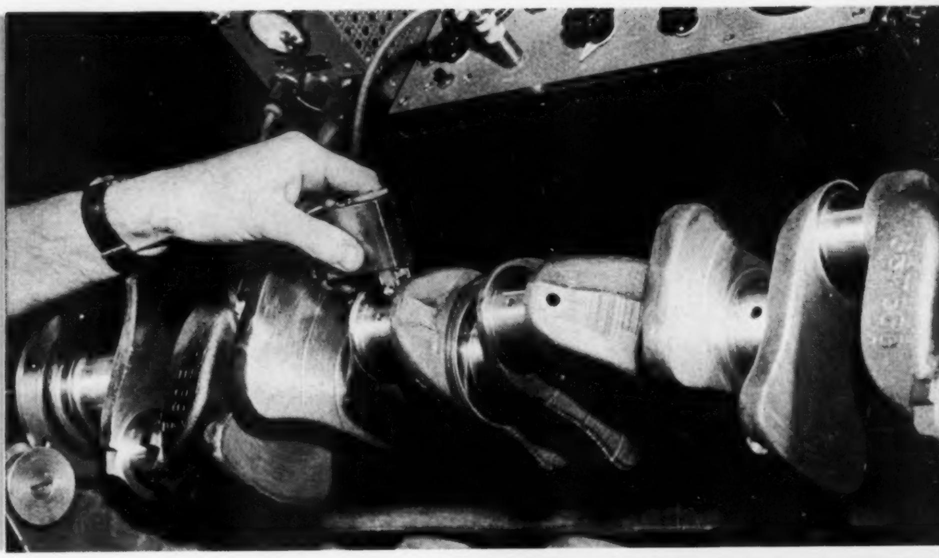
Wall-Draft Requirements: Walls normal to the parting plane of the die casting require draft or taper. This draft is not constant; it varies with the alloy and with depth of wall. Draft requirements for inside walls are shown in *Fig.* 1. Draft required on outside walls is one-half of that for inside walls. A separate standard (not yet issued) will cover draft requirements for corners. Also, requirements outlined in *Fig.* 1 do not apply to die-cast lettering, engraving or honeycomb designs.

Other Factors: In addition to the standards summarized here, standards on such engineering factors as cored holes, threads, fillets, alignment, stock allowances for machining, etc., will be issued in the future by American Die Casting Institute, 366 Madison Ave., New York 17.

Fig. 1—Draft requirements for inside walls of die castings. For outside walls, draft requirements are one-half of the values shown



Growth of the importance of surface finish is evidenced by the increasing number of articles written on the subject. This review of surface finish literature published during 1952 and 1953 supplements the review for the period 1945-1951, published in MACHINE DESIGN in 1952



Review of *Surface Finish Literature*

By John W. Sawyer
Bureau of Ships, Department of the Navy, Washington, D. C.

NEW METHODS of machining, improved materials, highly loaded components, and new needs and techniques combine to create new and more stringent demands on the designer and the manufacturer. For this reason machines are being built to closer tolerances, and many components must meet surface roughness specifications that were not even considered a few years ago. In some instances the degree of roughness of a component's working surface will spell the difference between satisfactory operation and complete failure.

During the past ten years a great amount of research and development has been conducted to investigate surface finish, surface roughness, and its relation to production cost, reliability and operation. Many excellent articles have been published that present results of these investigations. This published information is of value to the designer and the manufacturer, for it can aid in producing improved machines at lower cost.

The task of searching out specific subjects in the field of surface finish can be a very laborious one. To provide the designer and engineer with a ready guide to recent published material on surface finish, the writer has made a comprehensive review of literature published during 1952 and 1953. This is a continuation of the article entitled "Review of Surface Finish Literature," published in MACHINE DESIGN in September, October and November 1952.

This review covered the period from 1945 through 1951. Approximately 220 articles were abstracted, and some 300 subjects were referenced.

The present review, covering 1952 and 1953, indicates that more work is being done and experience gained each year on surface finish. This article covers 119 references and includes abstracts and an index listing subjects mentioned in the review papers. Approximately 520 subjects are listed in the index, with more than 1000 references to the papers covered in the review.

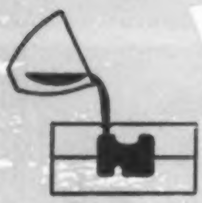
Material is grouped in two sections: abstracts which include the title, author, and publication, and a subject index with references to

(Continued on Page 333)

A Design Guide to

Production Characteristics of

ENGINEERING METALS

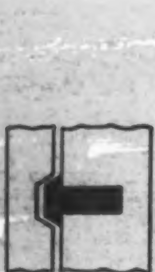


Which material to use?
What production steps are involved?

These two questions are so strongly linked in design of any part that they can only be considered as one common problem.

For every material there are optimum production processes.

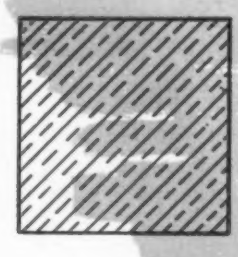
Some metals are particularly well suited to casting—some to forging—some to machining—some to stamping. Choice of a material depends strongly on how the part can be made.

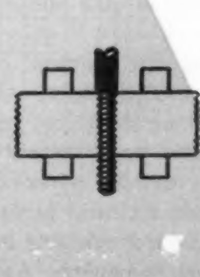


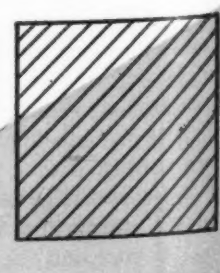
For every designed component, materials must be matched carefully to production.

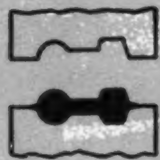
The problem is recurrent and troublesome—and vitally important to the success or failure of a part, an assembly, and a machine.

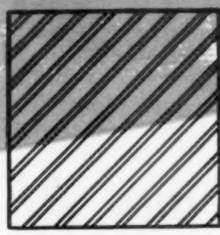
Here's design help—a comprehensive guide to the production characteristics of engineering metals.

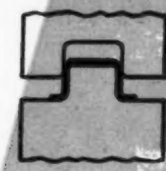






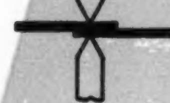


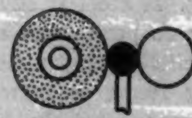


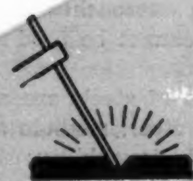


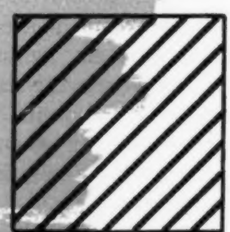
You will find these articles

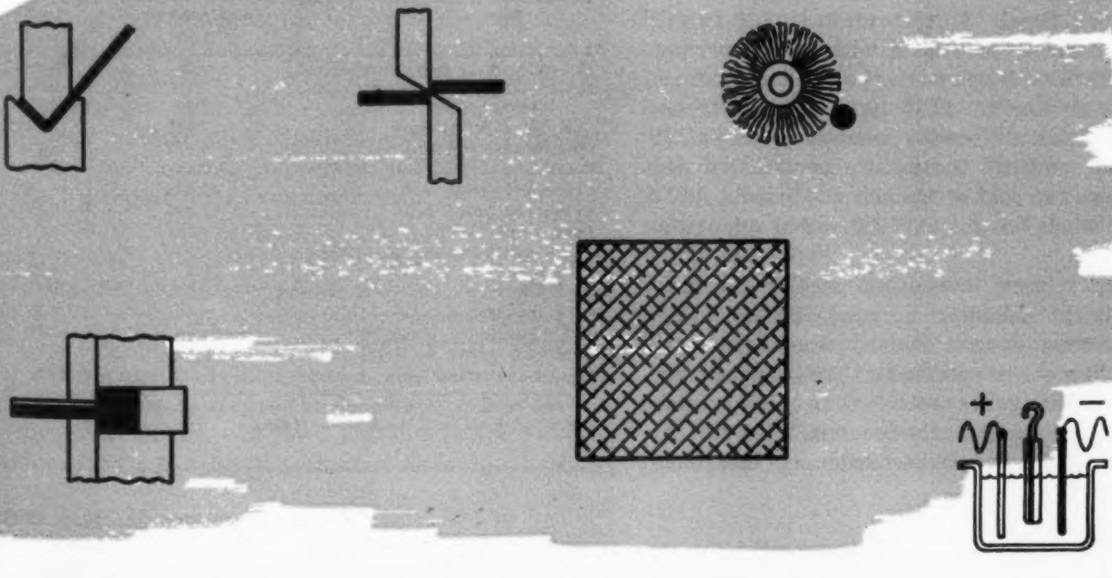
a co-ordinated approach directed at one major problem in materials selection. As part of a continuing program on materials used in design, these articles deal with the more common engineering metals. Main objective is to provide engineering help in matching a selected metal with its logical production methods.











Production Characteristics

Wrought Carbon and Alloy Steel:

Drawing Properties

By Carter C. Higgins
President
Worcester Pressed Steel Co.
Worcester, Mass.

THE FIRST requirement of a steel to be drawn and formed is that its chemical and physical properties permit an adequate range for working. If steel is stressed below the yield point, it takes no permanent set. If it is stressed beyond its tensile strength, it ruptures. Therefore, its working range is between its yield and ultimate tensile strengths. In hard tempers, for instance, the yield point closely approaches the tensile strength, and such steel cannot be used for drawing and forming.

Four general categories of steels are commonly used: low-carbon or mild steel; medium and high-carbon steels of limited drawability; low-alloy, high-strength steel; and structural and special alloy steels, which are usually heat treated or used where the alloying elements are required for special purposes such as corrosion resistance, strength at elevated or low temperature, etc. Stainless steels will not be covered in this discussion.

Low-Carbon Steel: A vast majority of formed and drawn parts employ steel with a carbon range of from 0.05 to 0.25 per cent, the most common of these being similar to AISI 1008, 1010, 1015 and 1020. Such steels are readily available, particularly the first two, and are the most economical to use. *Table* 1 shows the cost of 12-inch wide steels, 0.050-inch thick, when bought in 6000-pound quantities, f.o.b. mill.

Occasionally, very low-carbon steel is used for either electrical shielding purposes or for taking a good vitreous enamel finish. Sometimes 1019 steel or 1020 steel is specified (1019 being a somewhat higher manganese steel than 1020), since these steels are particularly recommended for carburizing or similar surface-hardening treatment.

On parts where functional requirements are not extremely critical, it may be desirable to leave actual selection of the grade to the fabricator, indicating merely the gage of "mild steel" as specification. Then the fabricator, in conjunction with the mill supplying the material, can work out the particular specification for the steel to be ordered to fit the fabricator's particular practices and processing, and the type of tooling planned.

Because of manufacturing variations in thickness or gage, in drawn parts, ordinarily where a wall thickness is shown on a cup or box, the fabricator assumes this is the gage of steel he should order to commercial tolerance. But the designer should recognize that this thickness will not necessarily be uniform throughout the whole part, and

Table 1—Cost of Steel*

Type	Cut Lengths (¢/lb)	Coils (¢/lb)
Hot-rolled strip steel; commercial	6.25	5.40
Hot-rolled, pickled and oiled deep-drawing sheets	7.35	6.50
Cold-rolled strip; hard	7.625	7.125
Cold-rolled strip; soft	8.075	7.575
Cold-rolled sheets; deep drawing	7.15	6.8
Cold-rolled 1045; soft	12.675	12.175
Cold-rolled 1075; soft	13.625	13.125
Long ternes	8.45	8
Corten (U. S. Steel) sheets; deep drawing	9.9	9.35
NAX (Weirton) strip; deep drawing .	10.925	10.425
6150; hot rolled	18.15	17.75
8630; hot rolled, annealed	19.70	18.30
4130; hot rolled, annealed	19.50	18.10
Type 302 stainless strip; annealed ...	49.25	48.5

*For 6000 lb of 0.050 by 12 inch wide steel; 24 inches wide, and coils; f.o.b. mill, packed, no freight.

Rocket motor case is an unusual and difficult stamping job from 0.037-inch thick SAE 4130 cold-rolled steel. The part measures $3\frac{1}{2}$ inches in diameter by 12 inches deep, and is drawn and redrawn five times with three anneals. The parts are heat treated and fixture quenched

Blank for X-ray tube is made from 0.098-inch thick, 28 per cent chrome iron. This material has expansion characteristics similar to the glass to which it is bonded. Extremely high heats are involved. Cups are $4\frac{1}{2}$ inches deep by $2\frac{1}{2}$ inches in diameter. Grain growth presented annealing problems

if another designation such as a minimum wall, or wall-variation or weight limit, is important, it should be taken care of by a note on the print.

Either the fabricator or the designer must determine whether the steel to be used is to be strip or sheet (or plate or bar for heavier sizes), whether the material will be hot rolled or cold rolled, in cut lengths or coils to fit fabricating equipment, or whether special specifications are needed such as killed steel, drawing quality, nonearing quality, stretcher levelled for flatness, or special finish requirements.

Most frequently 1008 or 1010 steel is used. The lower carbon 1008 steel has slightly better drawing properties, but where working is limited to shallow draws or forming, a 1010 steel may be preferable. This selection will vary with the tool design the fabricator uses. In today's processes, linked or progressive operations may permit the heat generated in one operation to be carried to the next operation, avoiding intermediate anneals on quantity runs, and this factor may give 1008 the preference over 1010. There is very little difference in the end product. For cold extrusion, 1012 or 1015 steel has more strength and seems to react better than 1008.

STRIP OR SHEET: Tolerances specified by the designer can have an important bearing on type of steel selected, and resulting cost.

Generally speaking, steel ordered wider than 12 inches is sheet steel, and sheet steel takes wider tolerances than strip steel since it is rolled on a wider mill from a more bulky mass. Some steel mills are rolling sheet steel continuously from 20 to 72 inches wide, and such steel, because of the spring of the rolls and the bearing friction on the ends of the rolls, will have a crown in the middle. If a stamping calls for 5-inch wide strip, the fabricator may buy strip steel to get a closer tolerance, or he may slit steel from a wide coil, depending on the tolerance acceptable in the dies or required on the finished part.

For close-tolerance work, Worcester Pressed Steel Co. prefers strip steel which costs more, but savings in tool repair or spoiled pieces may well offset the extra cost. Standard tolerances on strip and sheet are available from any mill. These tolerances can be reduced by paying an extra, and may be held extremely close on Sendzimir mills where the crown tolerance may be less than 0.001-inch on a 2-foot width. But such precision is, of course, more expensive.

Hot or Cold-Rolled Steel: In many cases, hot or cold-rolled steels may be used interchangeably, and it is difficult to say which has been used in a part after ironing or intermediate annealing. Today's efficient cold rolling mills have made cold rolled cheaper for most purposes up to 0.062-inch in thickness. Hot-rolled stock would have to be reheated to produce lighter gages, so there is no economy as compared with the secondary cold-rolling operation. Hot-rolled steel offers a rougher surface for better holding of lubricants but, for the same reason, is more difficult to polish. It is not as good for plating or finishing as cold-rolled steel. Furthermore, temper is not controlled unless the steel is specially handled, and tolerances are not as close.

Cold-rolled steel comes in various tempers ranging from full hard to dead soft. Full-hard temper steel is cold rolled with no annealing, and it does not carry an annealing extra. It is particularly satisfactory because it will blank, pierce or shave with a cleaner cut and less pull-down than soft or intermediate tempers; it also has

somewhat better tensile strength due to work hardening. If heat is required to apply a finish such as japanning, stresses in very hard cold-rolled steel may cause the part to go out of flat, and a softer steel is desirable.

While half-hard or quarter-hard steel can be formed, forming is more difficult and limited than with soft steel. Harder grades of steel are usually specified if the designer seeks higher physical properties than those obtainable from soft steel. Where these higher physical properties are required, it may be well to designate these tempers in connection with the part rather than trying to obtain them from the material specifications, because work hardening affects temper.

For drawing and coining work, a dead-soft steel is preferred. This is steel just as it comes from an annealing furnace. However, a dead-soft steel will show stretcher strains after it is worked, and it may be soft enough to tear easily. So the most frequently used steel is soft steel which has had a very light tempering or "skin rolling" to prevent this condition. An extra is charged for any intermediate-temper steel, the same as soft steel.

The fabricator faces a problem of aging with cold-rolled steel; the passage of time after the rolling process, plus effects of high storage temperatures and a smaller amount of "skin rolling," cause higher physical properties and loss of ductility. For this reason, an aluminum-killed steel may be specified (sometimes steel is killed with silicon or other deoxidizers). Killing retards the formation of gases within the ingot as it solidifies and also forms a more uniform composition throughout the ingot, which may lead to less fabrication spoilage. The surface, however, may not be as clean as with ordinary steels.

Depending on the part, hot-rolled or commercial quality steel may be adequate, or it may be better to order it pickled, oiled, and of drawing quality. Specifying drawing quality or drawing quality, special killed steel is a guide to the mill that their product should be of maximum ductility before shipment. The first costs an extra 25 cents per hundred pounds, and the latter 45 cents. Pickling removes mill scale and rust accumulated in transport, which helps to give a better surface and protect the dies of the fabricator.

Cold-rolled strip steel comes in three finishes: No. 1 is a dull finish, made on roughened rolls for good paint adhesion and lack of gloss; No. 2 is a regular bright finish, suitable for most requirements; and No. 3, which takes an extra, is particularly desirable for plating or polishing, if not marred by dies.

Frequently, steel is ordered prefinished. For in-

Hi-Pac cylinder for life belts involves top-quality steel for deep drawing. The threaded end is coined from 0.062 to 0.010-inch thickness for piercing, and gas is inserted through the necked end before sealing. Cylinders are tested for 8000 psi pressure. Steps shown are blank, lower left; cup, upper center; tube, lower right; tube cylinder as used (except plating), upper right. Intermediate operations omitted

Shallow drawn shield for an electrical instrument is made from a nonmagnetic, low-carbon ingot iron

stance, terne plate—cold-rolled steel coated with a lead alloy—costs about $1.00 per hundred pounds more than cold-rolled sheet. It provides an excellent paint base and will take a deeper draw than plain steel (if intermediate annealing is not involved) because the lead acts as a draw lubricant. Other cold-rolled steels are available with paint treatments, galvanized, electroplated, laminated with plastic films, or with various chemical-conversion coatings. These can provide an adequately corrosion-resisting or decorative surface at a lower cost than laboriously finishing each individual part.

In addition to these extra specifications are aircraft and gun-quality steels which are especially clear of imperfections, require more cropping of the ingot at the mill, and are usually furnished with certified physical tests and chemical analyses from the mills.

High-Carbon Steels: Medium-carbon steels have carbon ranges from 0.25 to 0.55 per cent, and high-carbon steels run from 0.55 to 0.95. Higher carbons than 0.95 are normally used for special purposes such as files and tool steels. As carbon increases, drawability decreases, response to heat treatment improves, and the surface is harder. Low-carbon steels can only be hardened by carburizing or cold working. By cold working low-carbon steel, a Rockwell hardness of B95 to 105 can be reached; and where steel has been cold extruded, over 100,000 psi tensile strength can be attained. Springs, gun parts, etc., are frequently formed of higher carbon steel, but only very shallow drawing is practicable. Most such steel is cold rolled.

Formed collar is not a drawn part, but shows a typical use of SAE 1040 cold-rolled steel. The collar is used to connect barrel to stock on a 12-gage shotgun. The center hole has been shaved

Low-Alloy, High-Strength Steels: Generally speaking, this class of steel has 25 to 50 per cent more strength than ordinary low-carbon steel, increased corrosion resistance, and can be easily welded. This added strength in equipment like railroad car parts and automobile bumpers permits somewhat lighter construction, and is well worth the premium of 2 to 3 cents per pound additional charged for these steels. These steels are somewhat more difficult to draw than regular mild steels, and even if gage can be reduced, parts will usually be somewhat more expensive.

Alloy Steels: Quite a range of regular and special alloy steels is available for stressed parts, most of them requiring heat treatment of the finished part to develop the full properties desired.

Chromium, nickel and molybdenum steels, such as 8630 and 4130 steels, can develop tensile strengths of 260,000 psi and still lend themselves to deep drawing when properly annealed. High manganese (12 to 14 per cent) steels are desirable for use in helmets, etc., but they are not easy to draw, since they are very sensitive to cold work—they give without rupturing. Steels in the 6000 series (6150, 6330) are being specified for flat parts requiring maximum surface hardness. Another useful family of steels are the silicon steels, which are very hard but have excellent properties for use as laminations in motors.

Apparently 4130 steel can develop about the highest strength properties of any commonly used steel in light gages and still lend itself to deep drawing. Such steel is used by Presteel in manufacturing Hi-Pac cylinders for storing gases at pressures of over 8000 psi. Experiences with 4140 steel, only 10 points higher in carbon, have been very unsatisfactory.

Certain high-chrome steels are desirable for low expansion in high-temperature uses, and for maintaining strength at these temperatures. In other cases, high temperature resistance can be given to steels by specifying some of the ceramic coatings on less costly alloys.

Production Characteristics

Wrought Carbon and Alloy Steel:

Machinability

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MACHINING operations are important despite recent advances in methods of pouring, pulling and pushing metals into shape. Time and effort spent in machining often control the cost of articles produced in large quantities. Machining costs can also be important in short runs on difficult materials or when large amounts of metal must be removed as chips. The cost of machining operations can be minimized by properly selecting workpiece and tool materials, using modern machines, and by applying the principles of metal cutting.

Machinability of steel is controlled by composition and microstructure. Machinability is a loosely defined term indicating the ease with which a metal can be machined to the desired shape, size, and surface finish. Steels differ in machinability because they are tailored, either by composition or heat treatment, to meet a variety of service requirements.

Comparative machinability ratings are established by testing different steels under standardized conditions. Since such studies usually involve metal cutting, it is not surprising that diverse testing procedures classify materials in the same qualitative order. To simplify matters, machinability investigations are usually conducted with single-point tools, but results can be applied to more complicated operations.

Approximate machinability ratings for carbon and alloy steels are given in *Table* 1. Some confidence can be attached to the ratings even though machining conditions can alter the comparisons slightly. An analogy can be drawn between machinability and corrosion resistance; both depend on the environment as well as the characteristics of the metals.

Machinability Ratings: Ratings in *Table* 1 can be used for preliminary estimates of speeds at

Table 1—Machinability Ratings and Machining Speeds for Hot-Rolled and Annealed Steels

Machinability rating*	165	130	100	91	80	72	68	62	58	53	48	42
Cutting speed† (fpm)												
High-speed steel tools...	280	225	170	155	135	120	115	105	99	90	81	71
Cemented carbide tools..	1100	875	725	625	550	500	475	450	400	370	325	275
Typical grades	High-sulphur. leaded steel	B1113 C1213	C1109 B1112 C1119	B1111 C1116 C1117 C1118 4140§ + Pb 8620 + Pb	C1120 C1141 C1144 4150 + Pb	C1137 C1141 C1144	C1010 C1025 C1030 C1050§ C1151 3130§ 4130§ 8630	2317 2330§ 3120 3140§ 4140§ 8620 8640§	C1040 1330§ 4145§ 4320§ 5150§ 6150§ 8650§	1320 1340§ 2330 2340§ 3135 4337§ 8650	C1065§ 2335 4820§ 9261§ 9317§	C1090§ 50100 52100

*Percentage of satisfactory speeds for cold-drawn B1112 steel as 100 using a cutting fluid and high-speed steel tools.

†Approximations for average turning cuts with feeds of 0.002-inch per revolution and 0.1-inch deep. Feeds should be reduced 60 per cent for light finishing cuts; by 90 per cent for forming cuts; and can be tripled for heavy roughing cuts.

§Annealed. Other data are for hot-rolled condition except for steels normally furnished cold drawn.

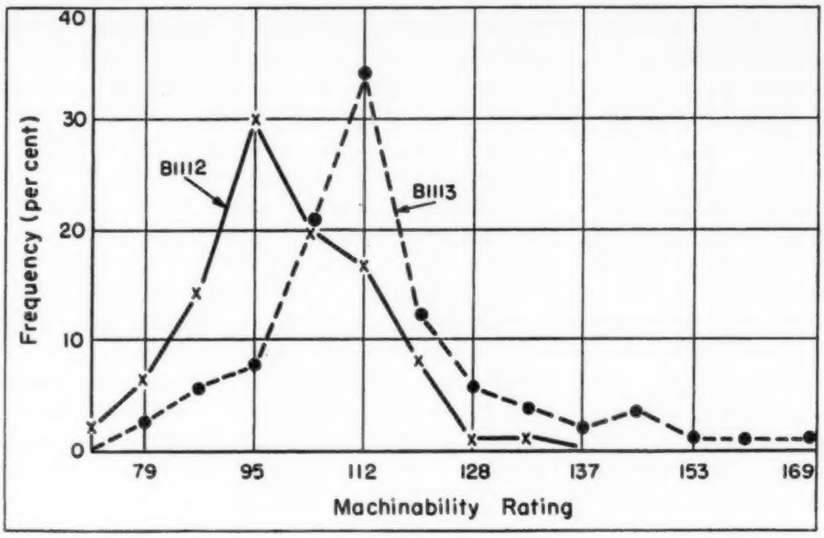

Fig. 1 — Distribution of machinability ratings for B1112 and B1113 steel samples

which different grades of steel can be machined. They represent the relative cutting speeds at which various steels are expected to give equivalent tool lives. For example, the table suggests that annealed leaded 4140 steel can be machined satisfactorily 91/62 times as fast as annealed 4140 steel.

The values are based on a machinability rating of 100 for cold-drawn B1112 steel. This brings up an interesting point which has not been widely publicized. Different lots of the same grade of steel can differ appreciably in machining quality, *Fig.* 1. The ratings were determined for samples from a comparatively large number of B1112 and B1113 heats of steel. Even though the average rating was 100 for the B1112 bars, about 22 per cent of them had ratings of 91 or less. Conversely, about 10 per cent of the samples had machinability ratings equal to or better than the average for the group of B1113 steels. A similar spread in quality is characteristic of any product produced in quantity. *Fig.* 1 emphasizes the fact that all machinability ratings are approximations. Nevertheless, average ratings are useful for suggesting starting points from which optimum machining conditions can be determined by experiment.

Average machinability ratings for different grades of steel vary in a five-fold range. That is, different steels will permit this large variation in production rate if all are machined with similar tools at equal feeds and cut depths. The spread may be more or less apparent if optimum machining conditions are not employed.

Effect of Composition: Chemical composition is one factor affecting the machinability of steel. Sulphur and lead are elements usually added to improve machining properties. Silver, bismuth, selenium, and tellurium are also beneficial but are not commonly used for this purpose.

Increasing the sulphur content of carbon and alloy steels, which ordinarily contain 0.04 per cent sulphur or less, considerably improves machining properties. For instance, C1109 steel can be machined satisfactorily at speeds about one-third faster than C1010. The two grades are similar in composition except that C1109 contains 0.08-0.13 per cent sulphur and C1010 contains 0.04 per cent sulphur or less.

The standard high-sulphur, free-cutting grades, B1113 and C1213, contain about 0.1 per cent phosphorus and 0.3 per cent sulphur. They can be machined at speeds double those employed for C1010 steel. They are usually cold drawn to secure good finish and an accurate shape. In this condition, the free-cutting steels exhibit strengths of about 75,000 psi and elongation values around 17 per cent in tensile tests. They are widely used because their mechanical properties are satisfactory for many applications.

Nevertheless, it should be noted that sulphur and phosphorus lower the ductility and toughness. On the other hand, lead apparently improves the machinability of steel without altering tensile properties. Addition of about 0.2 per cent lead to B1113 or C1213 steels allows them to be machined about 30 per cent faster than standard grades.

Of course, machinability is only one factor to be considered in selecting the best material for a particular part. Some parts require higher strengths than can be obtained from the low-carbon, free-cutting steels. The C1117 to C1151 series of resulphurized steels satisfy some of these requirements. Generally speaking, the resulphurized grades can be machined about 30 per cent faster than low-sulphur steels of equal carbon content.

In the cold-drawn condition, they have tensile strengths to about 125,000 psi. They can also be surface hardened or quenched and tempered.

Leaded steels with normal sulphur contents satisfy the need for free-machining steels having mechanical properties almost identical with standard steels. It is now possible to purchase lead-bearing counterparts of practically all standard AISI heat-treatable steels. Like the resulphurized steels, they are available in bar stock, rarely in plates. Considerable experience has been accumulated for the leaded 4140 and 8620 steels which have been available for some time. Leaded steels machine up to 50 per cent faster than lead-free alloy steels of comparable analysis. The increase in production rate permitted by leaded steels depends upon conditions in the particular machine shop. The presence of lead has no effect on response to heat treatment or on most mechanical properties. Leaded steels can be substituted for conventional steels in most applications with some saving in machining costs. Frequently, this saving outweighs the premium paid for the steel with improved machinability.

Perhaps a note of caution should be added about some possible limitations in using leaded steels. Practically no technical information has been published about the effect of lead in steel on the weldability, strength at elevated temperatures, or fatigue life at high stresses. The absence of such information may hamper designers who would like to specify leaded steels for more critical applications.

Lead and sulphur apparently improve machinability by acting as internal lubricants. Traditionally, they have been added to the workpiece material but not to the cutting tool. Recently, however, high-speed steels containing about 0.12 per cent sulphur have been marketed. Naturally, the additional sulphur makes the tool steel much easier to machine. In addition, cutting tools made from the high-sulphur steel may also perform better in service. Perhaps the sulfides in the cutting tools serve the same function as the graphite in graphitic tool steels used for dies. It will be interesting to learn whether or not double benefits can be secured from high-sulphur tool steels under a variety of conditions.

Effect of Microstructure: Microstructure is the fundamental characteristic controlling the machining properties of steels. Special additives such as sulphur improve machinability by introducing nonmetallic inclusions which occur as a separate phase. The size of such particles influences the extent of the benefits secured. Size and shape of the sulfide inclusions in two bars of B1112 steel are shown in *Fig.* 2. Careful tests showed that the two bars were almost identical in chemical composition and hardness. Although both contained equal amounts of sulphur, the machinability rating of the bar with stringy sulfides was only 2/3 as high as that for the other sample. Many other data support this conclusion that larger sulfides are more effective in improving machinability. This is one example of microstructure influencing machining properties.

Microstructures of steels usually vary because of differences in chemistry or heat treatment. For instance, the amount of the hard carbide phase present in normalized or hot-rolled steels increases with carbon content. Therefore, machining difficulties increase with carbon content in materials of this kind. The data in *Table* 1 suggest that increasing the carbon content of hot-rolled steel by 0.15 per cent lowers the machinability rating about 10 per cent.

Alloying elements such as nickel strengthen iron, and others like chromium harden the carbide phase, so alloying elements usually impair machinability. Annealing treatments which increase the proportion of free ferrite in alloy and medium-carbon steels permit higher production rates. Annealing such grades improves the relative machinability ratings about 10 per cent compared to the hot-rolled condition.

Tremendous improvements in tool life which can be effected by changing microstructure are shown in *Fig.* 3. The data were obtained with carbide tools taking 0.1-inch deep cuts at feeds of 0.015-inch (Field, Zlatin and Kahles). Most of the data are averages for tests on three different grades of 0.40 per cent carbon steel. They can be used to estimate the approximate tool life to be expected when machining specific microstructures at different speeds with carbide tools.

In addition to composition, inclusions and

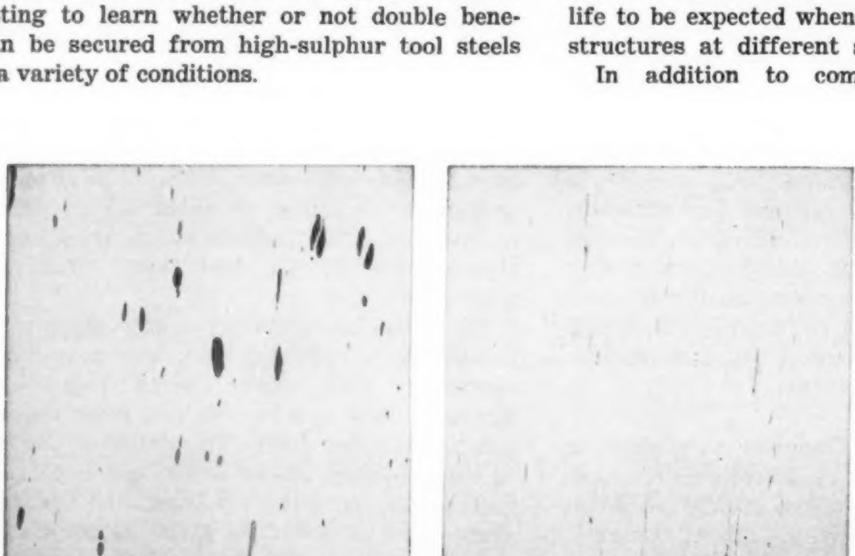

Fig. 2—Influence of sulfide particle size on machinability rating. Steels are both B1112 with almost identical compositions (steel at left has 0.001 per cent more phosphorus). But machinability rating of steel at left is 150; at right, only 106

strength, the grain size of steel can also affect machining properties. *Fig.* 4 shows the microstructure of a C1045 steel in the hot-rolled condition and after heating for one hour at 1600 F and cooling in air. The heat treatment produced a finer pearlitic grain size without changing the hardness. Although the samples were identical in chemical composition and similar in brinell hardness, the steel had a better machinability rating in the hot-rolled condition. The difference in ratings is appreciable and could be economically important. This comparison exemplifies the common observation that a structure with a medium-coarse grain size and with ferritic areas as large as possible is desirable in medium-carbon steels. Variations in microstructure of the kind illustrated in *Fig.* 4 can be produced by variations in cooling rate or in hot-working temperature. Such differences in processing are more often encountered in forgings than in rolled shapes.

Machining Conditions: Tool life corresponding to a particular machining speed is influenced to a certain extent by the dimensions of the cut. Cut depth and feed determine the area of the cut, and the latter variable has by far the greater effect on the permissible cutting speed. In fact, cut depth can ordinarily be increased without shortening tool life. The cutting speed should be reduced when the feed is increased. A cut depth about seven times the feed is used for many machining operations. For such aspect ratios, the cut area can be doubled if the cutting speed is reduced about 25 per cent. This means that the amount of metal removed before tools have to be resharpened can be considerably increased by taking as large cuts as practical. Naturally enough, tool forces and power requirements increase directly with cut areas if other conditions remain constant.

Almost all of the energy usefully expended in machining is converted into heat. The heat transferred to the tools causes them to soften, thus hastening dulling and failure by abrasion. The useful tool life depends principally on the cutting speed. Roughly speaking, a 20 per cent increase in cutting speed results in about half the tool life if other conditions are unchanged.

The efficient application of suitable cutting fluids greatly improves the life of cutting tools. With a good cutting fluid, high-speed steel tools last about 8 hours at speeds which cause failure in one hour when cutting dry. If the life of steel tools is satisfactory, the application of cutting fluids permits faster cutting speeds. Ordinarily, the permissible cutting speed is increased one-third by using cutting fluids with high-speed steel tools.

Cemented carbides are much harder and stronger than steels at the temperatures reached by cutting tools. Therefore, they permit higher cutting speeds than tool steels. Cutting speeds can usually be tripled by changing from wet cutting with high-speed steel tools to dry cutting with carbides. Suitably long tool life can usually be secured from carbides without employing cutting fluids.

Surface Finish: Components have to meet some

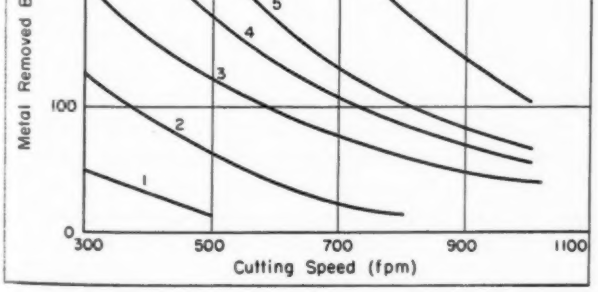

Fig. 3—Effect of microstructure and hardness on permissible cutting speeds with carbide tools (after Field, Zlatin and Kahles)

1. Tempered martensite ....400 bhn
2. Tempered martensite ....300 bhn
3. 100% pearlite ....200 bhn
4. Spheroidized ....180 bhn
5. 50% pearlite ....165 bhn
6. 30% pearlite ....140 bhn
7. 10% pearlite ....110 bhn

No. 1 to 6 contain 0.40 C; No. 7 contains 0.20 C.

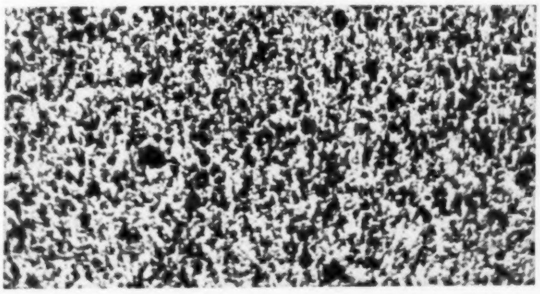

Fig. 4—Influence of microstructure on machinability of a C1045 steel at 155-160 bhn hardness. Steel at top is hot-rolled with a machinability rating of 58; at bottom, the steel has been normalized at 1600 F and has a machinability rating of 51

requirements for surface finish. Generally speaking, smoother surfaces cost more than rougher ones, but the smoothest finish is not always the most desirable. Optimum finish depends on the cost and the final application of the part. A smooth finish is especially desirable in parts subject to high or alternating stresses.

There has been comparatively little attention devoted to the quantitative effects of machining and material variables on surface finish. Ordinarily, machining conditions can be chosen to give suitable production rates and then modified if surface finish is unsatisfactory. The qualitative information available is usually sufficient to suggest the type of changes to be made.

Smearing of chip fragments on the workpiece and ridges left by the cutting tool are the principal causes of surface roughness. Faster machining speeds are particularly helpful in improving surface finish. Roughness can also be minimized by reducing the feed or by increasing the rake angle of the cutting tool. Stronger steels usually develop better surface finishes than weaker steels when machined under similar conditions. All of these changes suggested for improving surface finish tend to shorten tool life. Consequently, it can be deduced that steels with better machinability usually give smoother surfaces.

Production Characteristics

Wrought Carbon and Alloy Steel:

Weldability

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MOST commercial carbon and alloy steels can be welded satisfactorily provided suitable welding procedures, processes and materials have been specified. In addition, the weldment should be properly designed. Under these conditions, failures in welding deposits and in the heat-affected weld zones are highly unlikely.

The design engineer, in specifying welding, should consider several factors: (1) design and fabrication requirements, (2) welding processes, procedures and equipment available, (3) properties of the various engineering materials and, particularly, their weldability, and (4) selection and specification of the proper electrodes or filler rods, fluxes or gases.

For example, groove and edge design of the sections to be joined depends upon the welding process used. In butt welds, welded with covered electrodes, a $\frac{1}{16}$ to $\frac{1}{8}$-inch root opening (gap) between the sections to be joined is preferred. For inert-gas tungsten-arc welding, tight butting should be specified. To allow proper torch manipulation, a wider groove angle is usually specified for inert-gas welding than for metal-arc welding with covered electrodes. Submerged-arc welding, because of its deep penetration characteristics, permits welding of smaller grooves than necessary for metal-arc welding with covered electrodes.

Careful evaluation of effects of variations in welding procedures and the different welding processes and welding materials, are necessary to keep fabrication cost to a minimum. Desired quality of welding and service conditions to which the weldment is to be exposed must also be considered.

For example, under critical service conditions,

edge and groove preparation by machining and careful fit-up may be necessary, such as in the butt welds of high-pressure piping and pressure vessels, *Fig.* 1. Edge and groove preparation by flame cutting and grinding may be sufficient in many less severe applications where fit-up may not be as critical, *Fig.* 2.

Future articles will consider a number of these factors, with particular emphasis on materials to be welded, selection of electrodes and rods, and cost evaluation. The present discussion, however, will cover the basic welding processes, and weldability of carbon and alloy steels.

Weldability: Many interpretations are given to weldability. Generally, in evaluating weldability, the engineer should consider (1) the ease with which a weld can be made in a particular material with a particular welding process and procedure, and (2) the subsequent mechanical behavior of the welded joint. As such, weldability is directly concerned with the properties and characteristics of the weld and of the adjacent base-metal zone which has been heated by the welding operation (the so-called "heat-affected zone"). Weldability is further influenced by section thickness, design of the weld joint, welding procedure (current, voltage, electrode size, torch tip size, rate of travel, stringer or weave beading, etc.), position (flat, vertical, overhead or horizontal), temperature of the section being welded, cooling rate, and effects of postheat treatments after welding.

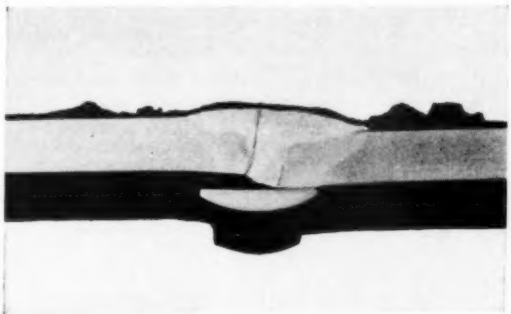


Fig. 1—Above—Cracks through carbon-steel pipe caused by stress corrosion and originating at notches formed by improper fit-up. Welds made with good fit-up did not crack under the same service conditions

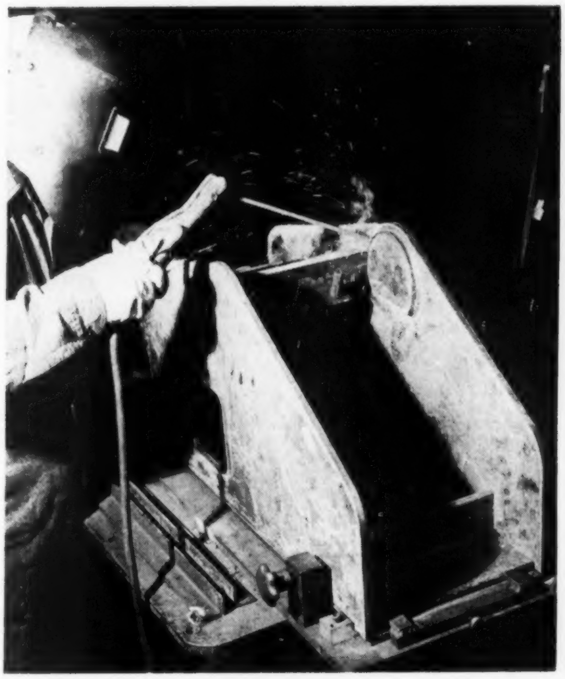


Fig. 2—Right—Tack welding of fixtured hangar assembly in which the parts have been cut by automatic flame-cutting procedures

Welding Processes: The major welding processes as applied to the welding of carbon and low-alloy steels are summarized in *Table* 1. This table is based primarily upon common usage, and *not* upon the relative merits of one method over another. Shape, size and thickness of the parts to be welded also influence preference for one method over another.

Submerged-arc welding offers advantages in automatic production welding, particularly on steels of medium and heavy wall thickness. It is used extensively in welding of seams and butt joints in pressure vessels and piping. In production, automatic submerged-arc welding is also practical on smaller sections where motor-driven positioners are available, *Fig.* 3.

Inert-gas carbon or tungsten-arc welding are extensively used on small sections of thin wall thicknesses. The inert-gas metal-arc process offers definite advantages in the automatic seam and butt welding of parts of light and medium wall thicknesses. The recent adaptation of this process to shielding with carbon dioxide or nitrogen, instead of argon or helium, will make this process more competitive with submerged-arc welding.

Resistance-welding processes are also used with excellent results. The best welding conditions vary somewhat with the alloy content of the steel and the hardening characteristics of the weld and heat-affected zones.

In addition to the processes listed in *Table* 1, other processes such as atomic-hydrogen welding, flash welding, pressure-gas welding and brazing are also practical for certain particular sizes, shapes and joint dimensions.

Carbon Steels: Weldability of carbon steels is primarily a function of their carbon content, factors such as weld thickness, geometry and tem-

Table 1—Welding Process Chart: Carbon and Alloy Steels

Steel	Shielded Metal-Arc	Sub-merged Arc	Inert-Gas Tungsten Arc	Inert-Gas Metal-Arc	Oxy-acetylene	Resistance	Thermit
Carbon steels							
Low carbon	1	1	2	2	1	1	2
Medium carbon	1	1	2	2	2	2	2
High carbon	2	3	3	3	2	3	3
Structural low-alloy steels (*Table* 2)	1	1	2	2	2	3	3
Low-alloy, high-strength steels (*Table* 3)							
0.12 max C	1	1	2	2	2	3	3
0.12-0.30 C	1	1	2	2	2	4	3
SAE steels (*Table* 4)							
Nickel	1	1	2	2	2	2	3
Nickel-chromium	1	1	2	2	2	4	3
Others: 0.30 mar C	1	1	2	2	2	2	3
Others: 0.30-0.50 C	1	1	2	2	2	3	3
Others: over 0.50 C	2	3	3	3	2	3	3
Chromium-molybdenum steels (*Table* 5)							
½ Cr, ½ Mo to 1¾ Cr, ½ Mo	1	1	1	1	2	4	3
2 Cr, ½ Mo to 3 Cr, ½ Mo	1	1	1	1	2	4	3
5 Cr, ½ Mo to 9 Cr, ½ Mo	1	1	2	3	2	4	3

1—Commonly used with excellent success; 2—Used with good success; 3—Occasionally used with good success; 4— Not used

Table 2—Welding Recommendations: Common Low-Alloy Steels

Steel	ASTM Specification No.	Grade	Composition (per cent) C	Mn	Si	Ni	Cr	Mo	Others	Welding Recommendations* Electrodes†	Preheat and Interpass Temp.§
Mn	A242-52T	..	0.24 max	1.30 max	....	....	....	....	....	E70XX E7015, E7016	Up to 200 F Not required
Mn-V	A225-54T	A	0.18 max	1.45 max	0.15-0.30	....	....	....	0.09-0.14 V	E70XX, E80XX‡ E7015, E8015, etc.**	Up to 200 F Not required
	A225-54T	B	0.20 max	1.45 max	0.15-0.30	....	....	....	0.09-0.14 V	80XX E8015, E8016	Up to 300 F Up to 200 F
C-Mn-Si	A299-54T	..	0.28-0.31 max††	0.90-1.40	0.15-0.30	....	....	....	....	E70XX, E80XX‡ E7015, E8015, etc.**	Up to 300 F Up to 200 F
Cr-Mn-Si	A202-54T	A	0.17 max	1.05-1.40	0.60-0.90	....	0.30-0.60	....	....	E70XX, E80XX‡ E7015, E8015, etc.**	Up to 200 F Not required
Mn-Mo	A302-54T	A	0.25 max††	0.90-1.30	0.15-0.30	....	....	0.45-0.60	....	Same as Cr-Mn-Si, Type A	
Cr-Mn-Si	A202-54T	B	0.25 max	1.05-1.40	0.60-0.90	....	0.30-0.60	....	....	E80XX, E90XX‡ E7015, E8015, etc.**	Up to 300 F Up to 200 F
Mn-Mo	A302-54T	B	0.25 max††	1.10-1.50	0.15-0.30	....	....	0.45-0.60	....	Same as Cr-Mn-Si, Type B	
Ni	A203-54T	A, B, C	0.27 max††	0.80-0.90 max††	0.15-0.30	2.00-2.60	....	....	....	E7015-C1, E8015-C1, etc.**	Up to 300 F
	A203-54T	D, E	0.23 max††	0.80-0.90 max††	0.15-0.30	3.25-3.75	....	....	....	E8015-C2, E9015-C2, etc.**	200-400 F
Cr-Mo	A301-54aT	A	0.21 max	0.80 max	0.15-0.30	....	0.50-0.75	0.45-0.60	....	E70XX-B2, E80XX-B2	Up to 200 F
	A301-54aT	B	0.17 max	0.65 max	0.15-0.30	....	0.80-1.15	0.45-0.60	....	E7015-B2, E8016-B2, etc.**	Not required

*Postheat treatment at 1100-1250 F for 1 hr per inch of thickness is recommended for all alloys.

†Strength values of electrodes should correspond to strength of the alloy steel grade. Usually, the higher the carbon and alloy content, the higher the strength requirements for the electrode.

§Use lowest preheat temperatures for sections up to ½-inch thick and highest values for sections over 2 inches thick, with intermediate temperatures at intermediate thicknesses. Preheating temperatures should also be higher for carbon and alloy contents in the upper part of the composition range.

‡Except low-hydrogen types EXX15 and EXX16.

**Also corresponding EXX16 low-hydrogen electrodes.

††Actual max content depends on specific grade or plate thickness

Table 3—Welding Recommendations: Typical Low-Alloy, High-Strength Steels

Steel	Nominal or Typical Composition (per cent) C	Mn	Si	Cr	Ni	Mo	Cu	Others	Welding Recommendations Recommended Electrode	Preheat and Interpass Temp.*
Armco high tensile	0.12 max	....	....	....	0.50 min	0.05 min	0.35 min	....	E60XX† E6015, E6016	Up to 200 F Not required
A. W. Dyn-El	0.11-0.14	....	....	....	....	....	0.40	....	E60XX† E6015, E6016	Up to 200 F Not required
Chromium-copper-nickel	0.12 max	0.75	....	0.75	0.75	....	0.55	....	E70XX† E7015, E7016	200-400 F Up to 200 F
Chromium-manganese	0.40	0.90	....	0.40	....	....	....	....	E80XX	400-600 F
Chromansil	0.15	1.35	0.75	0.50	....	....	....	....	E90XX	400-700 F
Corten	0.12 max	0.20-0.50	0.25-0.75	0.50-1.25	0.65 max	....	0.25-0.55	0.07-0.15 P	E70XX† E7015, E7016	200-400 F Up to 200 F
Hi-Steel	0.12 max	0.50-0.90	0.15 max	....	0.45-0.75	....	0.95-1.30	0.12-0.27 Al	E70XX† E7015, E7016	200-500 F Up to 300 F
Jalten	0.35 max	1.25-1.75	0.30 max	....	....	....	0.40	....	E80XX	400-600 F
Manten	0.25 max	1.10-1.60	0.30 max	....	....	....	0.20 min	....	E80XX	400-600 F
Mayari R	0.12 max	0.50-1.00	0.10-0.50	0.40-1.00	0.25-0.75	....	0.50-0.70	....	E70XX† E7015, E7016	Up to 300 F Not required
NAX	0.10-0.20	0.70	0.80	0.60	....	....	....	0.12 Zr	E70XX† E7015, E7016	Up to 300 F Not required
Otiscoloy	0.12 max	1.25	0.10 max	....	....	....	0.50 max	....	E60XX† E6015, E6016	Up to 200 F Not required
Silten	0.40	0.70-0.90	0.20-0.30	....	....	....	....	....	E80XX	400-600 F
U.S.S. Carilloy T-1	0.18 max	0.70-1.00	0.12-0.25	....	0.70-1.00	0.35-0.50	0.20-0.40	0.03-0.08 V	10015, 10016, 12015, 12016	200-400 F
Yoloy	0.05-0.35	0.30-1.00	....	....	1.75	....	1.00	....	E70XX, E80XX† E7015, E7016, E8015, E8016	200-600 F 100-400 F

†Except low-hydrogen types EXX15 and EXX16.

*Use lowest preheat temperature for sections ¼ to ½-inch thick and highest value for sections over 2 inches thick, with intermediate temperatures at intermediate thicknesses. Preheating temperatures should also be higher for carbon and alloy contents in the upper part of the composition range. Since most of these high-strength steels are fabricated in sheets or thin plates (up to ¼ inch), preheating is generally not required, unless the minimum recommended temperatures exceed 400 F.

perature of joint being constant. As a general rule, precautions necessary to deposit a sound weld increase with the carbon content of the base metal. Precautionary methods are preheating, use of low-hydrogen electrodes, proper groove preparation, accurate fit-up, etc.

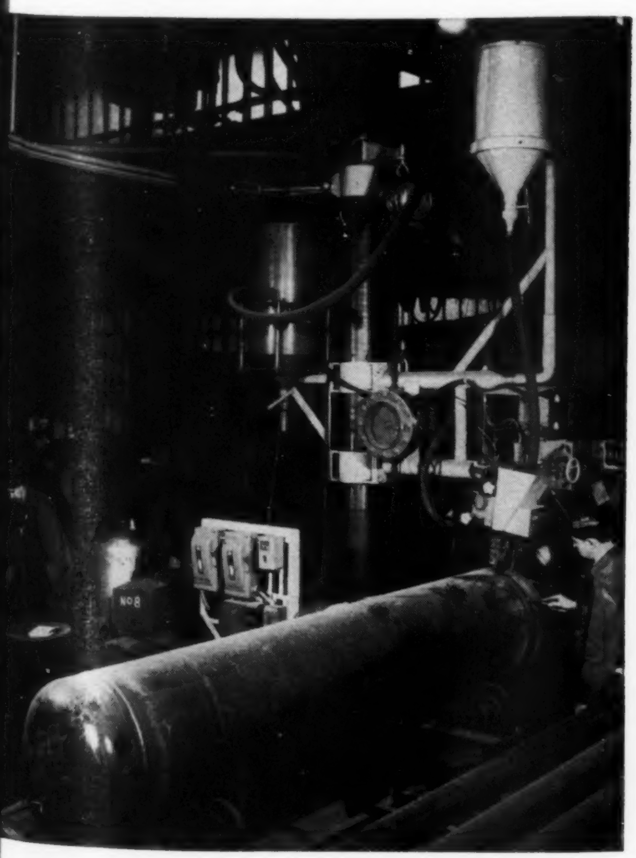
LOW-CARBON STEELS: The mild or low-carbon steels containing up to 0.30 per cent carbon are readily weldable by most of the commercial welding processes. However, there are a few exceptions.

In metal-arc welding, the very low-carbon steels (less than 0.10 per cent) are somewhat susceptible to formation of porosity in the weld. This porosity may be minimized by employing E6020 or E6030 electrodes and other methods such as using slower welding speeds and a short arc length.

Inert-gas arc welding of rimmed-steel grades may result in weld-metal porosity and, in extreme cases, in leaks where weldments are under pressure in service. However, porosity may be prevented by painting a fine aluminum emulsion over the joint area prior to welding or by means of special filler metals to which a small amount of aluminum has been added as "deoxidizer." The semikilled steel grades generally are not adversely affected by the inert-gas arc welding processes.

Preheating usually is unnecessary unless very heavy sections are welded, or unless the welding operation is made at subfreezing temperatures. In the latter case slight torch heating to bring the steel joint up to about 100 F should be employed. Where it is important to produce weldments of minimum ductile-to-brittle transition temperature, preheating to temperatures between 200 and 400 F sometimes may be desirable.

Fig. 3—Automatic submerged-arc welding of fillet weld of cap cover plate onto tubular section, using a motor-driven positioner



Postheating is not essential unless required by the respective codes for piping, boilers, pressure vessels, etc., in which final stress-relieving heat-treatments may be specified. For example, the ASME *Boiler and Pressure Vessel Code* (*Interpretations,* Case No. 1181) and the ASA *Code for Pressure Piping* require stress-relieving of carbon-steel piping and vessels of wall thicknesses ¾-inch or greater. Temperatures between 1100 and 1250 F are most commonly used.

MEDIUM-CARBON STEELS: Steels with a carbon content between 0.30 and 0.50 per cent can be satisfactorily welded by the various electric-arc, resistance and gas welding processes.

Rapid cooling produces hard martensite in the heat-affected zone, which is brittle and susceptible to under-bead cracking. This zone may also exhibit a relatively high ductile-to-brittle transition temperature. The hardened zone is not readily machinable. Preheat treatments and interpass temperatures between 300 and 600 F are generally highly recommended to introduce more desirable properties. The heavier the section thickness and the greater the carbon content, the higher should be the preheating temperatures. When low-hydrogen electrodes (E6015 and E6016) are used, preheat and interpass temperatures between 200 and 400 F are usually sufficient to avoid cracking.

After welding, slow and uniform cooling to room temperature is desirable. Small weldments may be buried in materials such as asbestos or sand to retard the cooling rate further.

Postheat treatments between 1100 and 1250 F for 1 hr per inch of section thickness may be desirable to improve the metallurgical structure, increase ductility, and relieve residual stresses.

HIGH-CARBON STEELS: Steels containing over 0.50 per cent carbon are rarely welded, except in the repair of cracked or worn parts. Oxyacetylene and shielded metal-arc welding are most frequently used. The submerged-arc welding process is occasionally used to overlay worn surfaces. Thermit welding has also been satisfactorily employed.

Preheating to 500 to 600 F is desirable, followed by postheating to 1300 to 1400 F. Low-hydrogen type steel electrodes (E6015 and E6016) are preferred. Either special covered steel electrodes or austenitic stainless-steel electrodes are also occasionally used.

Alloy Steels: As a general rule, welding difficulties for alloy steels increase in proportion to the

degree of hardening developed in the heat-affected zone adjacent to the weld metal—the result of martensite formation. Slow cooling rates in conjunction with suitable preheat treatments may have to be employed to minimize or prevent martensite formation which may contribute to underbead and weld-metal cracking.

Structural Low-Alloy Steels: On structural alloy steels, electrodes or welding rods which produce weld deposits of mechanical properties equal to those of the alloy steel are generally recommended, regardless of differences in the chemical composition of the base steel. Typical welding recommendations are given in *Table* 2.

Low-Alloy, High-Strength Steels: The low-alloy, high-strength steels, generally sold under specific proprietary trade names, usually contain small alloy additions of nickel or manganese, plus copper, silicon, chromium or molybdenum. They are characterized by good resistance to atmospheric and other mildly corrosive environments. Most alloys are designed to provide yield-strength values between 50,000 and 80,000 psi and tensile-strength values between 70,000 and 110,000 psi.

Carbon content is usually kept below 0.12 per cent. This minimizes the hardening characteristics and crack sensitivity of these steels. Most alloys, therefore, when used as sheets or thin plates do not require preheating, particularly when low-hydrogen type electrodes are used. Plates exceeding ¼ to ½-inch in thickness may require preheating along the weld area.

In shielded metal-arc welding, mild-steel E60XX electrodes may be satisfactory since weld deposits may develop tensile strength as high as 80,000 psi as a result of alloy pickup from the base steel. Where higher strength is desired, low-alloy steel E70XX, E80XX and E90XX electrodes may be required. Because of the greater crack sensitivity of the low-alloy steel electrodes, preheating may be advisable when alloy-steel electrodes instead of mild-steel electrodes are used. Typical welding recommendations are given in *Table* 3. Where corrosion is a factor, it is sometimes necessary to use core wires of the same compositions as the base steel.

Submerged-arc welding is extensively used to weld the low-alloy, high-strength steels. The high welding speeds and uninterrupted deposits possible where long seams are to be made make this process highly economical. Because of the deep penetration characteristics of submerged-arc welding, mild-steel filler wires are usually satisfactory. Preheating is generally not necessary.

Stress-relieving heat treatments, when required, should be carried out between 1100 and 1250 F.

Table 4—Welding Recommendations: SAE and AISI Steels

Steel	SAE Designations	Composition (per cent) C	Mn	Cr	Ni	Mo	Welding Recommendations: Electrode	Preheat and Interpass Temp.* (F)	Postheat Treatment for Stress Relief (1 hr/in. thickness)
ain carbon	1006–1027	0.06–0.29	....	....	....	....	E60XX	Not required†	Not required
	1030–1050	0.028–0.55	....	....	....	....	E70XX, E80XX§ E7015, E8015, etc.‡	300–600 100–600	Recommended, 1100–1250 F Recommended, 1100–1250 F
	1052–1080	0.47–0.88	....	....	....	....	E90XX, E100XX	500–800	Recommended, 1100–1250 F
anganese	1320–1330	0.18–0.33	1.60–1.90	....	....	....	E90XX§ E9015, E9016	200–550 Up to 550	Optional, 1100–1250 F Optional, 1100–1250 F
	1335–1340	0.33–0.43	1.60–1.90	....	....	....	E100XX	300–600	Recommended, 1100–1250 F
ickel	2317–2330	0.15–0.33	....	....	3.25–3.75	....	E8015–C2, E9015–C2, etc.‡	Up to 500	Recommended, 1100–1250 F
	2340–2345	0.38–0.48	....	....	3.25–3.75	....	E9015–C2, E10015–C2, etc.‡	400–700	Recommended, 1100–1250 F
	2512–2517	0.09–0.20	....	....	4.75–5.25	....	E9015–C2, E10015–C2, etc.‡	400–700	Recommended, 1100–1250 F
ickel-chromium	3115–3125	0.13–0.28	....	0.55–0.75	1.10–1.40	....	E80XX, E90XX§ E8015, E9015, etc.‡	200–500 Up to 500	Optional, 1100–1250 F Optional, 1100–1250 F
	3130–3140	0.28–0.43	....	0.55–0.75	1.10–1.40	....	E90XX, E100XX	400–700	Recommended, 1100–1250 F
	3141–3150	0.38–0.53	....	0.70–0.90	1.10–1.40	....	E100XX	600–800	Recommended, 1100–1250 F
	3310–3316	0.08–0.19	....	1.40–1.75	3.25–3.75	....	E9015, E10015, etc.‡	400–700	Recommended, 1150–1300 F
olybdenum	4017–4028	0.15–0.30	....	....	....	0.20–0.30	E70XX, E80XX§ E7015, E8015, etc.‡	100–400 Up to 200	Recommended, 1100–1250 F Recommended, 1100–1250 F
	4032–4053	0.30–0.56	....	....	....	0.20–0.30	E80XX, E90XX§ E8015, E9015, etc.‡	300–600 200–600	Recommended, 1100–1250 F Recommended, 1100–1250 F
	4063–4068	0.60–0.72	....	....	....	0.20–0.30	E100XX, E120XX	600–800	Recommended, 1100–1250 F
hromium	5115–5120	0.13–0.22	....	0.70–0.90	....	....	E70XX, E80XX§ E7015, E8015, etc.‡	100–350 Up to 250	Recommended, 1100–1250 F Recommended, 1100–1250 F
	5130–5135	0.28–0.38	....	0.75–1.10	....	....	E80XX, E90XX§ E8015, E9015, etc.‡	250–450 Up to 450	Recommended, 1100–1250 F Recommended, 1100–1250 F
	5154–5150	0.38–0.56	....	0.70–1.15	....	....	E90XX, E100XX	350–550	Recommended, 1100–1250 F
anganese-nickel-molybdenum	8620	0.18–0.23	0.70–0.95	....	0.40–0.60	0.15–0.25	E70XX, E80XX§ E7015, E8015, etc.‡	100–350 Up to 250	Recommended, 1100–1250 F Recommended, 1100–1250 F
	8630	0.27–0.33	0.70–0.95	....	0.40–0.60	0.15–0.25	E80XX, E90XX§ E8015, E9015, etc.‡	200–500 Up to 500	Recommended, 1100–1250 F Recommended, 1100–1250 F

*Use lowest preheat temperatures for sections to ½-inch thick and highest alues for sections over 2 inches thick with intermediate temperatures at intermediate thicknesses. Preheating temperatures should also be higher for arbon and alloy contents in the upper part of the composition range.

†Preheating to 200 F may be helpful for very heavy sections of steel with over 0.20 per cent carbon.

§Except low-hydrogen types EXX15 and EXX16.

‡Also the corresponding EXX16 low-hydrogen electrodes.

Ordinarily such postheat treatments are not necessary, except where particular Code requirements are to be met.

SAE AND AISI STEELS: Typical welding recommendations for a characteristic group of SAE and AISI carbon and alloy steels are given in *Table* 4. The low-carbon alloy grades with less than 0.15 per cent carbon generally may be welded in the same manner as mild steels and do not require preheat treatments, particularly when low-hydrogen electrodes are used.

For the higher-carbon grades, low-hydrogen electrodes are preferred, since they tend to produce welds of higher quality, minimize cracking and porosity, and reduce the required preheating and interpass temperatures by about 200 F for steels of which the preheat temperature without low-hydrogen electrodes is less than 400 F. When a steel requires a preheat of 400 F or higher without low-hydrogen electrodes, then the preheat temperature should not be lowered when low-hydrogen electrodes are used.

Postheat treatments may also be required. For most alloys, temperatures between 1100 and 1300 F

are recommended. A few alloys and weld deposits may be detrimentally affected at these temperatures as the result of temper brittleness.

CHROMIUM - MOLYBDENUM ALLOY STEELS: The chromium-molybdenum steels are highly air-hardening. To prevent the formation of very hard and crack-sensitive heat-affected zones and weld deposits, preheat and interpass temperatures between 300 and 700 F should be maintained.

Typical welding recommendations are given in *Table* 5. Electrodes or welding rods of the same chromium content as the base steel are generally recommended. Almost all electrode manufacturers furnish electrodes and welding rods in only the 1 Cr, ½ Mo and 2 Cr, 1 Mo type compositions for welding alloys up to 2½ Cr, ½ Mo grades. Experience has proved this to be satisfactory, provided the higher alloy 2 Cr, 1 Mo electrodes and welding rods are specified for the 1¾ Cr, ½ Mo to 2½ Cr, ½ Mo grades.

Table 5—Welding Recommendations: Chromium—Molybdenum Steels

Steel	ASTM Specification No.	ASTM Specification Grade	Welding Recommendations: Electrodes††	Welding Recommendations: Preheat and Interpass Temperature* (F)	Welding Recommendations: Postheat Treatment† (F)
½ Cr, ½ Mo	A155-52aT A301-54aT A335-53T	½ Cr P2 A	E70XX-B1, E80XX-B1	300-400‡	1250-1325
1 Cr, ½ Mo	A155-52aT A213-54T A301-54aT A335-53T	1 Cr T12 P12 B	E80XX-B2, E90XX-B2	300-400	1300-1350
1¼ Cr, ½ Mo, ¾ Si	A155-52aT A199-54T A200-54T A213-54T A335-53T	1¼ Cr T11 T11 T11 P11	E80XX-B2, E90XX-B2	300-400	1300-1350
1¾ Cr, ¾ Mo	A199-54T A200-54T A213-54T A335-53T	T3 T3 T3 P3	E80XX-B3, E90XX-B3	400-500	1300-1375
2 Cr, ½ Mo	A199-54T A200-54T A213-54T A335-53T	T3b T3b T3b P3b	E80XX-B3, E90XX-B3	400-600	1300-1375
2¼ Cr, 1 Mo	A155-52aT A199-54T A200-54T A213-54T A335-53T	2 Cr T22 T22 T22 P22	E8015-B3, E9015-B3, etc.§	400-600	1325-1400**
2½ Cr, ½ Mo, ¾ Si	A199-54T A200-54T	T4 T4	E8015-B3, E9015-B3, etc.§	400-600	1325-1400**
3 Cr, 1 Mo	A199-54T A200-54T A213-54T A335-53T	T21 T21 T21 P21	5 Cr, ½ Mo (E502)	600-700	1350-1400**
5 Cr, ½ Mo	A155-52aT A199-54T A200-54T A213-54T A335-53T A357-54T	5 Cr T5 T5 T5 P5 ..	5 Cr, ½ Mo (E502)	600-800	1350-1400**
7 Cr, ½ Mo	A199-54T A200-54T A213-54T A335-53T	T7 T7 T7 P7	7 Cr, ½ Mo; 9 Cr, 1 Mo	600-800	1350-1400**
9 Cr, 1 Mo	A199-54T A200-54T A213-54T A335-53T	T9 T9 T9 P9	9 Cr, 1 Mo; 12 Cr (E410)	600-800	1350-1400**

*Use lowest temperature for sections up to ½-inch thick and highest values for sections over 2 inches thick, with intermediate temperatures for intermediate thicknesses.

†1 hr per inch of wall thickness; ½-hr minimum.

§Also the corresponding EXX16 low-hydrogen electrodes.

‡May be necessary only to prevent cracks in root passes.

**After welding, the weld should be allowed to cool to below 600 F before the recommended postheat treatment is applied.

††Suffixes -B1, -B2 and -B3 refer to new AWS-ASTM subclassifications specifying electrodes containing ½ Cr, ½ Mo; 1¼ Cr, ½ Mo; and 2¼ Cr, 1 Mo; respectively.

In submerged-arc welding several manufacturers furnish bare carbon steel electrodes (wires) with special alloy steel fluxes to deposit $1\frac{1}{4}$ Cr, $\frac{1}{2}$ Mo or $2\frac{1}{4}$ Cr, 1 Mo weld-metal compositions. This has not been proved as satisfactory and acceptable as the use of bare $1\frac{1}{4}$ Cr, $\frac{1}{2}$ Mo or $2\frac{1}{4}$ Cr, 1 Mo welding electrodes with "unalloyed" fluxes.

Generally, after welding, the weld should be allowed to cool to below 600 F, but not to less than 300 F. This should be followed immediately by the postheat treatments between 1150 and 1400 F shown in *Table* 5. For alloy grades containing up to 5 per cent chromium and less than $\frac{1}{2}$ inch thick, a minimum of 30 minutes at these temperatures may be sufficient. For the 7 and 9 per cent chromium grades, the minimum heating period should be at least 1 hr in any thickness. Heavy sections of all grades should be heated for at least 1 hr per inch of thickness.

In the past, austenitic stainless-steel electrodes E309 (25 Cr, 12 Ni), E310 (25 Cr, 20 Ni), and E312 (29 Cr, 9 Ni) have been used for welding the chromium-molybdenum alloy steels, particularly when postheating was not possible. This, however, is no longer considered good engineering practice. Such dissimilar metals are most undesirable in structural welds exposed at service temperatures exceeding 800 F.

Production Characteristics

Wrought Carbon and Alloy Steel:

Forging Characteristics

PHYSICAL properties in the forged ferrous metals are usually developed by suitable heat-treating procedures, which impart properties required for the particular application.

Development of physical properties inherent in a metal also results from the mechanical working of the metal in the forging process. This type of refinement and improvement is effected by controlled directioning and positioning of the inherent fiber-like grain structure of the metal, commonly termed "grain flow."

Greatest strength of the material lies in the direction of the flow lines, and elaborate pains are taken to insure that these are located to best advantage in forging for critical service.

Based on material supplied by Steel Improvement & Forge Co., Cleveland, Ohio.

Since the fiber structure or flow lines in wrought metals are known to be in the direction of working, flow lines in rolled forging bars are parallel to the length of the bars. The forging stock is positioned in the first forging operation to suit the particular requirement and to place the flow lines to the best advantage. The exact positioning to be attained and the subsequent forging operations thus required depend upon the shape and complexity of the forged part and upon the direction of the important stresses on the part when in service. Although the actual grain structure of the metal can be controlled by heat treatment, the fiber-like structure of the forging is retained, regardless of subsequent heat treatment. It is general practice today to specify grain-flow position for all aircraft parts and on many other industrial applications.

Tests on specimens taken from both longitudinal

Table 1—Carburizing Steels

Tensile strength	50,000-120,000 psi
Yield point	35,000-100,000 psi
Elongation in 2 in.	15-35%
Reduction in area	40-65%

AISI or SAE No.	Application
1015	For moderate conditions and maximum economy with fairly good physical properties. Where conditions of maximum uniformity are desired, a guaranteed carburizing quality steel should be specified.
2317	For greater core toughness than obtainable with 1015 and for minimum distortion. Machines well and is suitable for single quench operations in many cases.
3115	An economical alloy steel for greater strength than obtained in plain carbon steel. Forges and machines well and hardens uniformly.
3316	High strength and toughness obtained for heavy pressures, impact and wear. A sensitive steel that requires good heating equipment for the forging and heat treating operations, as well as careful handling to develop maximum properties.
4615	Offers deep, hard case with good core properties and fine machinability.
4815	For greater core strength than 4615. Comparable with 2317 for general physical properties.
6120	Offers high surface hardness with good core properties and resistance to shock and vibration. This alloy minimizes the tendency toward grain growth. Suitable for single quench operation in many cases.
8615, 8720	Properties comparable to the standard alloy specifications and can be used for most of their applications, where the higher alloyed steels are not readily available.

and transverse directions in wrought steels indicate no appreciable difference in tensile or ultimate strength, and in yield strength.

However, there is a difference in percentage of elongation and in reduction of area. Average figures show about 1½ times greater percentage elongation, and about 2 times greater percentage reduction of area for the specimens taken in the longitudinal direction.

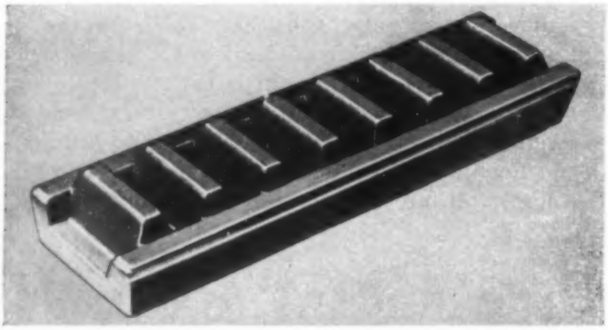
But the largest variation indicated between the two types of specimens is in impact strength as indicated by notched-bar impact tests. Specimens cut in the longitudinal direction show about 3 times more impact strength than those in the transverse section. This indicates the importance of grain-flow positioning on parts subject to impact. shock, vibration, stress concentrations, and where unusual or unexpected stresses may be encountered.

Ferrous metals for forging (exclusive of stainless) fall into two classes:

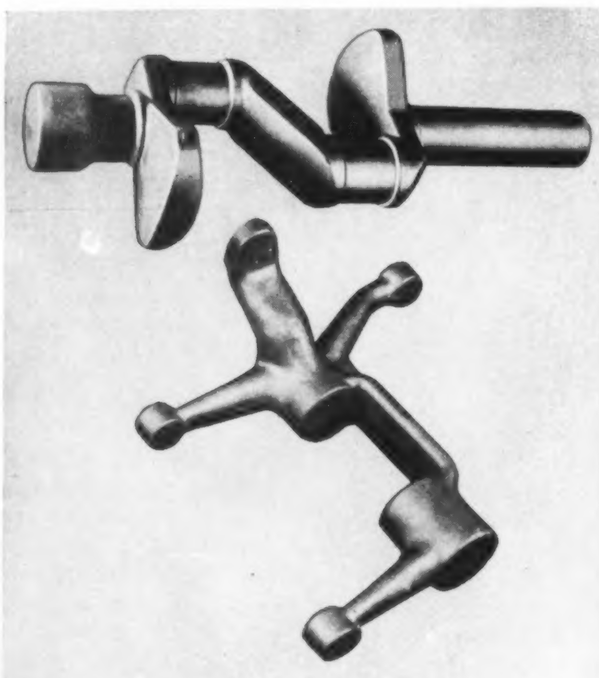
Using closed-impression dies for hot-working the steel, a forging drop hammer mechanically works the metal to the specified shape, often in several forging operations. Flash is trimmed from the forged part either hot or cold. Punching operations may be performed on trimmer dies simultaneously with flash shearing

Carbon Steels: Straight carbon steels are used for most general applications. They are the simplest of the steels which use the carbon content to impart potential mechanical properties and which are developed by heat treatment in the medium and higher carbon grades. Forgings produced from this material find a wide use for general purposes, have good properties, and are the most economical of the steels.

Low-carbon steels (up to about 0.20 per cent content) find extensive use for parts which require carburizing properties, ductility, moderate strength, impact strength, weldability and ease of fabrication, but do not need hardenability or fine machinability. Wrist pins, brackets, arms, ma-



Parts with pockets and recesses, such as this pinion rack, require careful forging technique, die design, and material selection to obtain maximum strength



High strength-to-weight ratio is a feature of forgings with thin sections, such as this crankshaft forging, upper, and fastener yoke, lower. Important where fluctuating loads, impact or similar stresses occur, high-strength characteristics of the metal are accented by drop forging

Table 2—General-Purpose Steels

Tensile Strength	50,000-80,000 psi
Yield point	30,000-50,000 psi
Elongation in 2 in.	25-50%
Reduction in area	45-70%

AISI or SAE No.	Application
1020	For general forged products where economy is combined with fairly good physical properties and where heat treatment or fine machine work is not a requirement.
1120	Machining properties improved over those of 1020, but shows a slight reduction in general physical properties.
1030	A good general straight-carbon steel with physical properties improved over 1020 and with better machining characteristics. Responds to heat treatment. A fine steel for a good balance in strength, toughness, and machinability.
1040	For purposes similar to 1030, but where larger sections are encountered and deeper hardness penetration is desired. Responds more sharply to heat treatment than 1030.

Table 3—Medium-Strength Steels

Tensile strength	80,000-100,000 psi
Yield point	50,000- 70,000 psi
Elongation in 2 in.	20-35%
Reduction in area	35-60%

AISI or SAE No.	Application
1050, 1060	Straight-carbon steels possessing good machining properties with somewhat higher physical properties than the lower carbon steels but at the sacrifice of some ductility. Good properties for an economical steel on the medium and large sections. Responds nicely to heat treatment.
3120	Greater strength and toughness with improved hardenability as compared with the plain carbon steels. Forges and handles easily, machines well, and possesses its best properties in the heat-treated state.
6120	Used interchangeably with similar purpose alloy steels in the same carbon range. Particularly valuable in the field of parts subject to vibration. Heat treats well and is not readily subject to excessive grain growth.
8620, 8720	Offer properties comparable to the standard alloy specifications and can be used for most of their applications, where the higher alloyed steels are not readily available.

Table 4—Intermediate-Strength Steels

Tensile strength	100,000-125,000 psi
Yield point	75,000-100,000 psi
Elongation in 2 in.	17-27%
Reduction in area	35-55%

AISI or SAE No.	Application
1330	Offers better machinability, hardenability, and physical properties than are obtainable in the medium straight-carbon steels.
2330, 2335	Good natural toughness with resistance to shock and impact. Machines well with properties improved by heat treatment. A fine analysis for many of the more difficult applications.
3130, 3135	Greater strength and toughness with better hardenability than straight carbon steels. Forges well and machines readily. Heat treatment is desirable to bring out the best properties.
4130	This composition can be used interchangeably with the 2300 and the 3100 series alloy steels with similar carbon content. Has a fine balance of strength and toughness when heat treated. It is a desirable steel for machining in the heat-treated state.
8630, 9437	Offer properties comparable to the standard alloy specifications and can be used for most of their applications, where the higher alloyed steels are not readily available.

chine handles, covers, cams, bodies, and latches are typical items for which low-carbon steels are usually specified.

Medium-carbon steels ranging in carbon content form about 0.25 to 0.50 per cent offer a fine balance of properties for strength and stiffness, good machining, wear, and a response to heat treatment for improving many of the desirable characteristics. Connecting rods, shafts, brackets, valve parts, cylinder bodies and links are a few of the almost endless variety of parts made from medium-carbon steels.

Higher carbon steels offer greater stiffness, higher strength, better wearing properties and better response to heat treatment. The higher carbon content is especially desirable for large forged parts or those with heavy cross-section—large shafting, crankshafts, diesel engine parts, valves, etc.

Carbon steels with increased sulphur content are used where better machinability is preferred to maximum strength, while a higher manganese content permits use where improved machinability is desired without any sacrifice in strength.

Table 5—Medium-High-Strength Steels

Tensile strength	125,000-150,000 psi
Yield point	100,000-125,000 psi
Elongation in 2 in.	16-25%
Reduction in area	30-55%

AISI or SAE No.	Application
1340	Offers higher strength, greater toughness, and better hardening properties than plain carbon steels of similar carbon content. Has good machining properties.
2335	For machine parts where natural strength and toughness are desirable. Properties improved by suitable heat treatment. Has minimum distortion in heat treatment and machines well.
3140	An economical alloy steel with better general properties than plain carbon steels. A desirable composition on small and medium sized forged parts for a wide range of applications. Has good forging, machining, and heat treating properties, and shows best general properties when heat treated.
4140	Used interchangeably with similar purpose alloy steels of similar carbon content. A desirable steel where the machining operations are performed after heat treatment of the forged parts.
4340	Offers a maximum combination of hardness and resistance to severe stresses. A sensitive steel requiring good forging and heat treating equipment with careful handling to obtain the maximum results. Can be machined in the heat-treated state.
6145	Interchangeable with alloy steels of similar carbon content and strength. Particularly desirable to meet vibration and fatigue stresses and for pieces difficult to heat treat due to variation in section areas.
8640, 9440	Offer properties comparable to the standard alloy specifications and can be used for most of their applications, where the higher alloyed steels are not readily available.

Table 6—High-Strength Steel

Tensile strength	150,000-175,000 psi
Yield point	125,000-150,000 psi
Elongation in 2 in.	12-18%
Reduction in area	25-50%

AISI or SAE No.	Application
2345	For parts where natural strength and toughness are desirable. Best properties obtained by heat treatment. Has good machining properties and shows minimum distortion in heat treatment.
3150	A good steel where a balance of strength and hardness is desired. Has good hardenability in larger sections.
4150	Interchangeable with other similar strength alloy steels for general service conditions. A good composition for machining in the heat-treated state.
4340	Offers a maximum combination of properties for hardness and toughness on complex stresses. Requires experience and careful handling on good heating and heat-treating equipment for the best results.
6150	Interchangeable with chrome-nickel and chrome-moly alloy steels of similar carbon content. Desirable for parts subject to vibration and fatigue stresses and for heat-treated parts of varying cross-section areas.
8650, 9445	Offer properties comparable to the standard alloy specifications and can be used for most of their applications, where the higher alloyed steels are not readily available.

Alloy Steels: Commercial alloy steels include the use of one or more alloys in addition to carbon. A single combination is exemplified by the straight nickel series. Two-alloy combinations, such as chromium-nickel, chromium-molybdenum or nickel-molybdenum, are used extensively, and three or more alloys are found in many of the steels. Many desirable working properties are made available by the proper balance of alloys in the material, coupled with careful forging and heat treating. However, exacting heating methods and heat treating processes are required with the more complex alloys steels.

Generally speaking, additional alloys are used in steel to obtain physical properties which cannot be developed in the straight carbon series—greater toughness, increased depth of hardness, higher hardness, better wear, improved resistance to fatigue, shock or impact, and a higher factor of safety, to mention a few. The variety of these steels offers a good selection of material over a wide range of increased physical properties but, in general, an increase in alloy content also increases the difficulties of forging, heat treating and machining the parts.

While alloy steels are usually employed for highly stressed parts of engines, aircraft and machines, selection of the best grade for a given service condition depends upon many other factors, including design and shape of the part, amount and type of wear, and life expectancy of the part.

Comparison Tables: The data in *Tables* 1 to 6 offer a general guide in the selection of a suitable forging metal from the standard compositions normally available. Steels have been grouped according to general uses and for comparable tensile properties. Some discretion is necessary in making a final selection, for the indicated figures do not cover all factors necessary for complete specific comparison. Such factors as impact strength, resistance to wear, comparable machinability, or the working strengths at elevated and subnormal temperatures, have not been listed.

The tables list standard steels and are arranged in a manner to indicate given strengths as obtained by tensile tests of the material. Toughness or impact strength depends upon the condition of the heat treatment and upon the positioning of the grain-flow lines.

Production Characteristics

Wrought Carbon and Alloy Steel:

Cold Heading Properties

By David H. Samuelson
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PHYSICAL properties obtained in cold-headed parts are excellent, evidenced by the use of cold heading for precision aircraft fasteners requiring critical heat treatment to obtain physical properties of high standards.

Cold heading is an economical method of manufacture for parts ranging in diameter from approximately 1/16 to 1 inch. There is little or no scrap loss.

Production speeds range from 50 to 200 pieces per minute. Although large-volume production lends itself to cold heading, today many parts in relatively small quantities are being made.

Typical standard cold-headed items are screws, nuts and bolts. However, many similar items of a special nature, many of which do not have threads, are being made today, *Fig.* 1.

Cold-Heading Process: The process consists of feeding coiled drawn wire at room temperature into the machine. There, it is straightened and a part is cut off and positioned in a round hole die, slightly larger in diameter than the wire.

In the standard cold-heading machine, two blows are struck. The first blow, or coning hammer, is followed by the second blow, or a finishing hammer, both of which strike the end successively of the cut-off blank. These hammers upset the metal, forcing it to flow in the die and hammer to form thicker sections and, in some cases, intricate shapes. As much as $4\frac{1}{2}$ diameters of stock and even more can be upset by this method. A kick-out pin then ejects the part from the die. The sequence of operations is shown in *Fig.* 2. If desired, the part may be extruded in other sections to a smaller area approximately 30 per cent less than the original area.

The drawn wire is smooth and bright, and the cold-heading dies and hammers have excellent finish; consequently, cold-headed parts have a finish which is burnished and bright in appearance. Cold working the metal increases strength and is a check on the quality of the steel, since harmful defects will be noticeable after upsetting. The cold-heading operation causes grain flow of the steel to conform to the contour of the part. The resulting directional flow of the steel provides greatly increased resistance to vibration and shock.

Many parts made by cold heading do not require subsequent heat treatment. However, if the upset is large or of an odd shape, the cold working may tend to produce brittleness. This brittleness may be reduced by stress relieving. Steels having a carbon content over 0.30 per cent can be heat treated, quenched and tempered in order to obtain the desired strength.

Table 1—Cold-Heading Grades: SAE and AISI Steels

Carbon Steels*			
1008	1022	1038†	1110
1010†	1026	1041†	1137
1018†	1035	1108	
Alloy Steels			
1335 (Mn)	4037† (Mo)	5120 (Mn-Cr)	
1340 (Mn)	4130 (Cr-Mo)	8637† (Ni-Cr-Mo)	
3135 (Ni-Cr)	4137† (Cr-Mo)	8640 (Ni-Cr-Mo)	
3140 (Ni-Cr)	4140 (Cr-Mo)	8740 (Ni-Cr-Mo)	

*AISI carbon steel numbers are "C" numbers; i.e., C1008, C1010, etc. †Grades in predominant use.

Fig. 1—Cold heading as a process is widely used for fasteners, but is also suitable for a variety of other parts

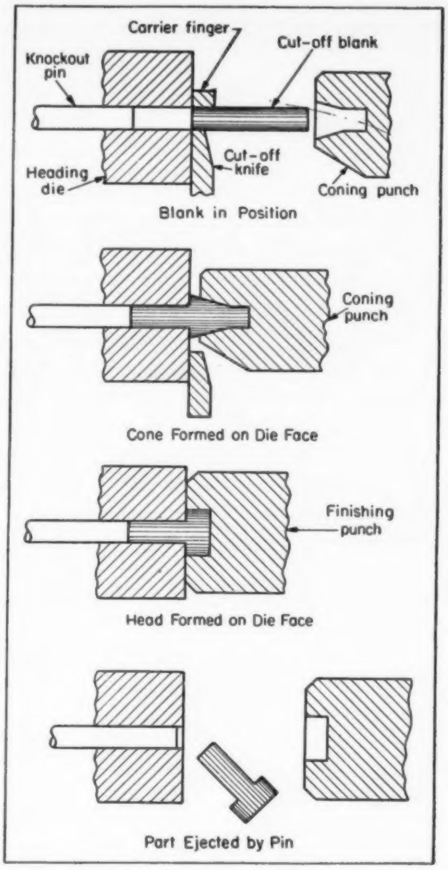

Fig. 2—Basic sequence of operations in cold heading

Cold-Heading Steels: *Table* 1 gives a list of cold-heading carbon and alloy steels. Grades with an asterisk are in predominant use today; the others are used in varying quantities, usually for specific applications.

Predominantly used grades should be given first consideration, since they are regularly used by cold-heading manufacturers. They are more readily available; heat treatment is better understood; they provide better performance; and price is usually lower.

Carbon Steels: C1010, a low-carbon steel, is used for commercial steel screws and miscellaneous cold-headed parts which have either no physical requirements or minimum tensile strengths of 55,000 psi. Machine screws, carriage bolts, rivets and cotter pins are made from this material. C1010 conforms to materials specified under SAE Grade 1. Physical properties which can be obtained are given in *Table* 2.

Low-carbon steel C1018 is used for cold-headed parts requiring greater strength than C1010. Fasteners such as low-carbon cap screws, machine bolts, plow bolts, slotted wood screws and tapping screws are made from C1018. Fasteners are ordinarily not heat treated; however, C1018 steel can be case hardened very successfully for use where resistance to wear or abrasion is desired.

Medium-carbon steels C1038 and C1041 are usually quenched and given a minimum temper of 800 F. These materials give excellent strength properties and are economical to use. They are used for heat-treated parts with physical properties shown in *Table* 2. However, higher minimum tensile strengths can be obtained if desired.

Alloy Steels: Physical properties ordinarily recommended for alloy steels are shown in *Table* 2. Higher minimum tensile strengths can be obtained, but are not ordinarily recommended. Heat treatment in all cases consists of a quench and minimum temper of 800 F.

Medium-carbon molybdenum alloy steel 4037 is used for medium and high-strength parts below ½-inch diameter. Medium-carbon nickel-chromium-vanadium alloy steel 8637 is used for medium and high-strength cold-headed parts, ½-inch diameter and over. Medium-carbon chromium-molybdenum alloy steel 4137 is used for medium and high-strength cold-headed parts in all cold-heading diameters.

Headability Ratings: In *Fig.* 3 are given headability ratings for grades of carbon and alloy steels in predominant use today. Headability is associated with plasticity, the ability of metal to undergo extensive deformation without rupture. Ductility of the metal, which is the measure of the permanent deformation before breaking under

stress in tension, is the best test to determine plasticity and headability.

The tension test gives two important indications regarding the ductility of the metal: ***Reduction in area*** and ***elongation***. Reduction in area is the difference between the original cross-sectional area and that of the smallest area at the point of rupture. The larger the percentage of change, the better the headability. Elongation is the amount of permanent extension in the vicinity of the break in the tension test, and is usually expressed as a percentage of the original gage length. Similarly, the greater the percentage of elongation the better the headability.

Headability ratings in ***Fig.*** 3 use as a base a rating of 100 per cent for C1010. It is noticeable when considering these headability ratings that the amount of carbon content in the steel plays an important part in the rating. The change from 0.10 per cent carbon in C1010 steel to 0.18 per cent in C1018 drops the headability rating 10 per cent. The change from 0.18 per cent carbon in C1018 to 0.38 per cent in C1038 drops the headability rating 20 per cent. Also, the change from 0.38 per cent carbon in C1038 steel to 0.41 per cent in C1041 drop the rating an additional 5 per cent.

Presence of alloys such as molybdenum, chromium, nickel, vanadium and manganese usually decrease headability of the alloy steel. However, it is interesting to note that the headability rating of 4037, a molybdenum alloy with 0.37 per cent carbon, is 5 per cent greater than C1037 with 0.38 per cent carbon, and 10 per cent greater than C1041 with 0.41 per cent carbon.

Table 2—Physical Properties: Predominant Cold-Heading Steels

No.*	SAE Grade, Description, and Size	Tensile Strength (1000 psi, min)	Proof Load (1000 psi)	Hardness Brinell	Hardness Rockwell
1010	Grade 1—Commercial Steel	55		207 max	B95 max
1018	Grade 2—Low-Carbon Steel				
	Length, 6 in. and under				
	Diam to ½-in.	69	55	241 max	B100 max
	Diam, ½ to ¾-in.	64	52	241 max	B100 max
	Diam, ¾ to 1½ in.	55	..	207 max	B95 max
	Length over 6 in.; all diam.	55	..	207 max	B95 max
1038, 1041	Grade 5—Medium Carbon Steel, Quenched and Tempered				
	Diam to ¾-in.	120	85	241-302	C23-32
	Diam, ¾ to 1 in.	115	78	235-302	C22-32
	Diam, 1 to 1½ in.	105	74	223-285	C19-30
1038, 1041	Grade 6—Medium-Carbon Steel, Quenched and Tempered, High Strength				
	Diam to ⅝-in.	140	110	285-331	C30-36
	Diam, ⅝ to ¾-in.	133	105	269-331	C28-34
4037, 8637, 4137	Grade 7—Medium-Carbon Alloy Steel, Quenched and Tempered, Medium Strength				
	Diam to ½-in.	130	105	269-321	C28-34
4037, 8637, 4137	Grade 8—Medium-Carbon Alloy Steel, Quenched and Tempered, High Strength	150	120	302-352	C-32-38

*SAE and AISI numbers; AISI carbon steel numbers are "C" grades, i.e., C1010, C1018 . . . C1041.

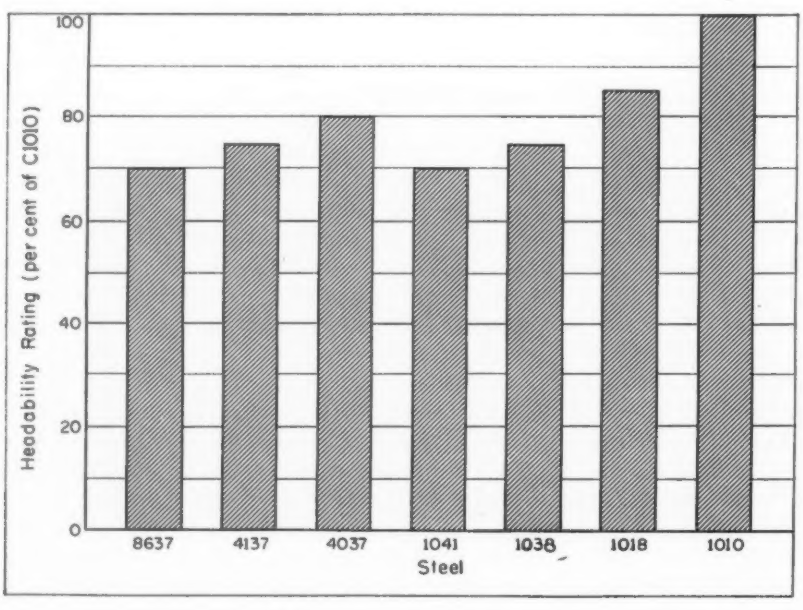

Fig. 3—Relative headability of main carbon and alloy steels used for cold heading

Production Characteristics

Wrought Carbon and Alloy Steel:

Hot Extrudability

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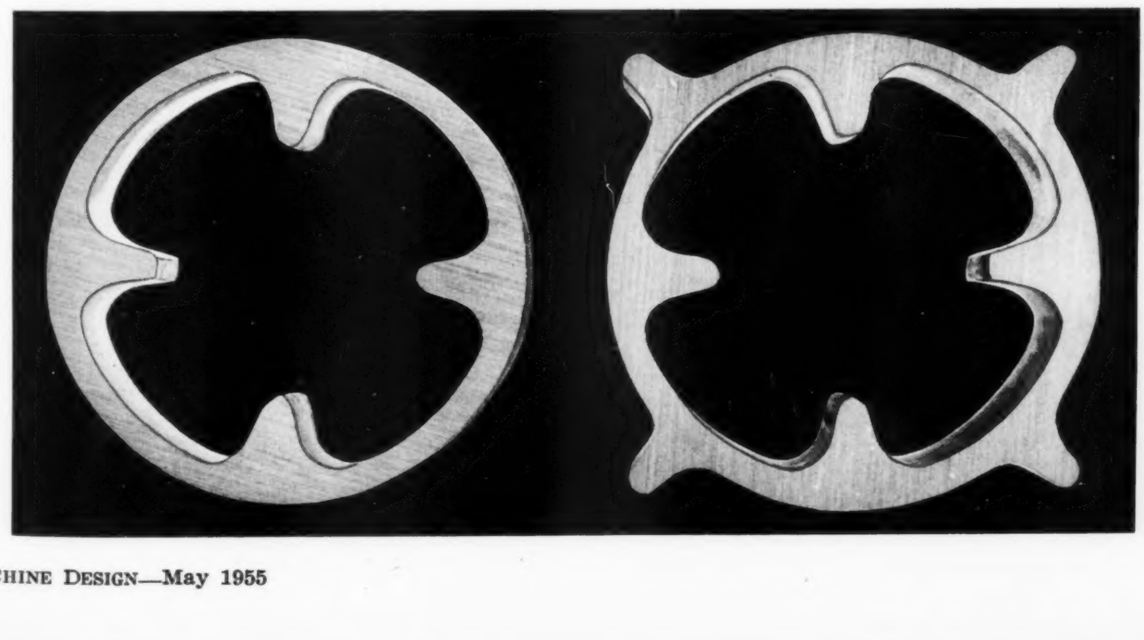
THE demand for metals with improved high-temperature strength, oxidation resistance and corrosion resistance has steadily increased over the years. Such improvements in metal properties are usually realized at the expense of hot workability. Methods and processes to produce these new alloys and metals do not always keep abreast with requirements, especially when the requirements demand variation in shape and form. Thus, use of many valuable alloy steels has been restricted because conventional hot working equipment does not permit economical processing.

At Babcock & Wilcox, full-scale research has been conducted on the extrusion possibilities of a number of standard and special alloys. Extrusion process used is the Ugine-Sejournet method, using molten glass as the lubricant. Major effort has gone into the extrusion of seamless tubing. But a considerable amount of attention has been given to the manufacture of solid and tubular shapes, in some of the more unconventional alloys.

This article summarizes the "standard" steels, stainless and higher alloys that can be extruded successfully. But other considerations also enter into the mention here of particular alloys. Tests

Fig. 1—Extruded internally finned tube, left, with $3\frac{1}{2}$-inch OD and 0.200-inch wall, is made from a 20 Cr, 2 Al alloy. Tube section at right, with internal and external fins, is extruded from type 304 stainless



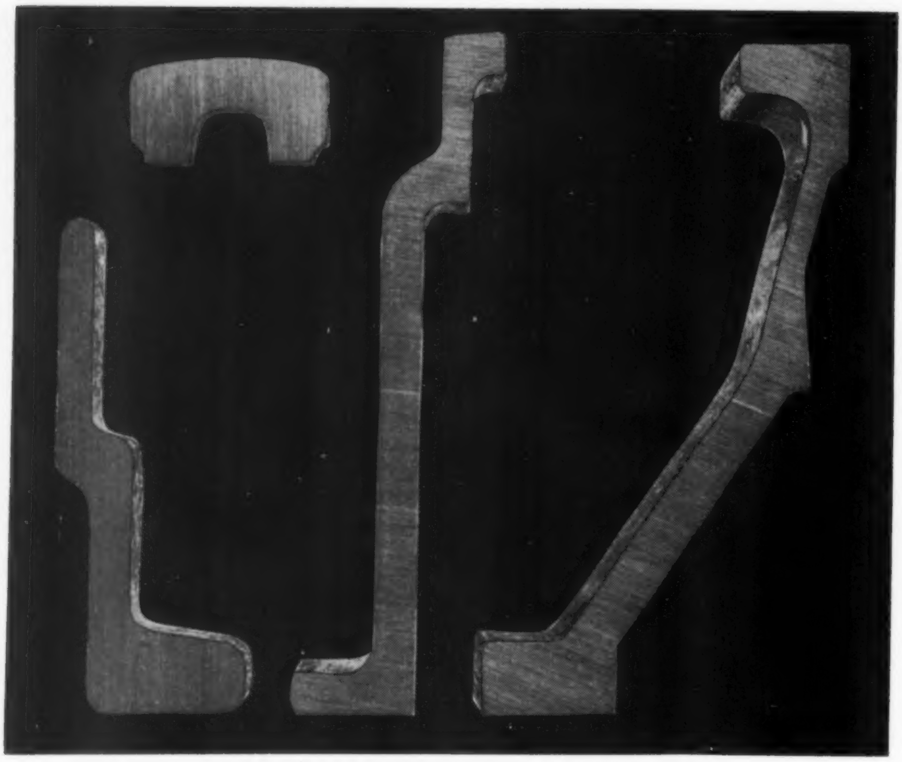


Fig. 2 — Solids and shapes are also possible. Smallest extrusion is for door frames of type 304 stainless. Larger sections, for aircraft use, are: type 310, left; AISI 1020, center; and 8620, right

were conducted on standard-size ingots, cast and further processed by routine mill methods so that forging and rolling practices to produce seamless tubing could be worked out. If extrusion into tubing was successful, then cold working on tube reducers and draw benches was attempted. Work on some alloys was discontinued because proper melting techniques could not be worked out. Some alloys could not be forged, others could not be extruded, and some could not be cold worked. The summary in this article describes the alloys for which suitable processing methods were developed.

When to Use Extrusions: Use of seamless tubing is so widespread that further mention is not needed here. But by extrusion, odd-shaped tubes can also be produced, which may be of advantage either for heat transfer or mechanical purposes. *Fig.* 1 shows a tube with internal fins and one with both internal and external fins.

Extruded solid shapes are used for three reasons:

1. Provision of shapes which cannot be rolled.
2. Provision of shapes not offered as standard production sections.
3. Provision of shapes in small unit quantities.

Shapes which cannot be rolled, or are not offered, may be in this category because excessive draft on some section may make rolling impractical, or the shape may simply not be offered in the grade of steel desired. Angles with one leg heavier than the other, or simple shapes that vary enough from the regular so that demand has never been sufficient to justify rolls for commercial supply, frequently force the designer to resort to expensive machining. Many of these shapes may be produced by extrusion.

When relatively small quantities of a new shape are desired, extrusion may well provide an economical source even when rolling is possible, but rolls are not presently available. Tools for extrusion can be produced for about $150 whereas rolls cost many times this amount.

Finally, there are many cases where 1000 pounds or less of a shape are required at intervals over a long period of time. Large-quantity orders would cause a large investment to be tied up in inventory, but a small quantity would require a rolling mill changeover with a prohibitive cost and disruption in mill schedules. In steel extrusion, the die is changed after every push, so that successive pushes may well produce different shapes. Thus an extrusion plant could produce as small an item as 150 pounds or one billet without prohibitive cost, assuming that the requirement is recurrent so that the die may be used up and its cost may be borne over a succession of such small items.

The majority of shapes produced are in the relatively easy-to-work alloys for these reasons. Most shapes have been for aircraft and aircraft-engine components. One of the most popular alloys for these applications is AISI 410.

Solid shapes have been successfully made from:

Low-carbon steel	Discaloy
20 Cr, 2 Al alloy	Armco 17-4 PH
Type 410 stainless	Zirconium alloy
Type 430 stainless	Titanium alloy
Type 304 stainless	

Solid rounds have been made from practically all alloys that have been extruded into tubing.

For pure molybdenum and molybdenum alloys, the extrusion press has been found quite necessary for economical processing. With conventional forging operations, initial breakdown from the cast ingot is costly both in time and yield. The extrusion press performs the initial breakdown with little loss in yield and at great time savings.

Solid shapes which have recently been extruded are shown in *Fig.* 2. *Fig.* 3 is a collection of typical shapes which may be extruded.

Extrudable Alloys: Steels, high alloys and several nonferrous materials which can be produced by hot extrusion are shown in *Table* 1, together with an indication of the types of sections which can be produced. Among this group are certain alloys which have been successfully extruded into seamless tubing, and which are of particular interest because of difficulty of production by other methods. These alloys will be covered in the following section.

TYPE 309 AND MODIFICATIONS, basically 25 Cr, 12 Ni stainless-steel alloys, have evoked considerable interest. Type 309S is an 0.08 per cent maximum carbon modification which has previously been available only as welded tubing. The nature of the service where much of it has been used precludes removal if a leak develops, so one variable is removed if seamless tubing is used.

Type 309 with carbon on the order of 0.30 per cent is used for high strength and oxidation resistance. An example of the type of service is radiant heating tubes. At present, centrifugal cast tubes are furnished for this application. Type 309S stabilized with columbium is required where welding may have to be performed during installation.

TYPE 310 WITH COLUMBIUM, a 25 per cent chromium, 20 per cent nickel stainless alloy is now available in the stabilized form for applications where welding is required.

TYPE 316 AND TYPE 317 WITH COLUMBIUM, chromium-nickel-molybdenum stainless alloys, can be utilized in applications where welding must be performed if they are stabilized with columbium.

ARMCO 17-4 PH, a chromium-nickel-copper alloy, is an age-hardening type of stainless steel which can be hardened by heat treatment to Rockwell C 40 to C 45. It has corrosion resistance approaching the standard 18-8 alloy.

NODULAR IRON or Ductile Iron is a cast iron treated with magnesium to promote the formation of graphite in nodular form which improves ductility. This alloy has been extruded into tubing, but cold working has not been successful as yet. Normally, this material is used in as-cast condition.

A-286 AND DISCALOY are both high-temperature alloys. A-286 is an austenitic iron-nickel-chromium alloy designed for service up to 1300 F. It is of considerable interest in jet engines and superchargers for applications such as turbine wheels and blades, frames, casings, afterburner parts, bolting and hardware. It is also an age-hardenable alloy. A similar alloy, Westinghouse Discaloy,

Fig. 3—Typical shapes possible by hot extrusion

has also been successfully extruded.

UNILOY 19-9 DL, another superalloy for use to 1200 F, is used for jet engine, gas turbine and turbosupercharger applications.

TYPE 420 STAINLESS is a high-carbon (0.15 per cent min) 12 per cent chromium alloy of interest where corrosion resistance and high hardness is required, for example, in valve parts.

TYPE 440C STAINLESS is a 1.00 per cent carbon, 18 per cent chromium ball-bearing steel for use under certain corrosive conditions. This has not been successfully cold worked.

TYPE 330 STAINLESS is a low-carbon modification of the cast 35 per cent nickel, 15 per cent chromium alloy. One application has been seamless tubular rivets for use in heat-treating baskets.

TIMKEN 16-25-6 is a high-temperature alloy which has been extruded satisfactorily. Cold working seems to be practical.

TOOL STEELS of several types have been successfully extruded into tubing, including the 18-4-1 high-speed steel grade.

A 0.50 per cent carbon, 16 per cent tungsten, 2.5 per cent chromium, 0.40 per cent vanadium tool steel has been successfully made into tubing for use as containers for extrusion of small automotive parts. Previously, these containers were made by drilling solid bars which was very expensive from a material standpoint.

Another type of tube to which extrusion is particularly well adapted is very heavy-wall tubing, which is difficult to produce by rotary piercing. This type of tubing is of interest in hollow die steels.

TITANIUM has been the subject of extensive efforts to develop processes for making titanium and its alloys available in seamless tubing. Commercially pure titanium grades A-55 and A-70 have been successfully extruded and cold worked, and can be obtained as seamless tubing. Extrusion into tubing has been accomplished on such titanium alloys as 6 Al, 4V and 3 Al, 5 Cr.

ZIRCONIUM has received a limited amount of work. Zircaloy No. 2, an alloy of tin and zirconium, can be extruded but cold-working processes have yet to be developed.

Table 1—Extrudable Steels, High Alloys, and Nonferrous Metals

Material	Composition (per cent)								Extruded into . . .		
	C	Mn	Si	Cr	Ni	Mo	Cb	Others	Tubing	Solids	Shapes
AISI 1020	0.20	0.50	0.15	....	....	....	....	....	Yes	Yes	Yes
AISI 4135	0.35	0.80	0.25	0.95	....	0.20	....	....	Yes	Yes	Yes
AISI 4140	0.40	0.90	0.25	0.95	....	0.20	....	....	Yes	...	...
AISI 52100	1.00	0.35	0.25	1.40	....	....	....	....	Yes	...	...
AISI 410	0.15 max	0.75	0.50	12.50	....	....	....	....	Yes	Yes	Yes
AISI 420	0.15 min	0.75	0.50	13.00	....	....	....	....	Yes	...	...
AISI 430	0.12	0.75	0.50	16.00	....	....	....	....	Yes	...	...
AISI 431	0.18	0.75	0.50	16.00	1.75	....	....	....	Yes	...	...
AISI 440C	1.00	0.75	0.50	17.00	....	....	....	....	Yes	...	...
Croloy 20-A	0.15	0.75	0.50	20.00	....	....	....	2.0 Al	Yes	...	Yes
AISI 443	0.20	0.75	0.50	22.00	....	....	....	1.00 Cu	Yes	...	...
AISI 446	0.15	1.00	0.50	27.00	....	....	....	....	Yes	...	...
AISI 329	0.15	0.75	0.50	27.00	4.00	1.00	....	....	Yes	...	...
17-4 PH	0.05	....	....	16.50	4.00	....	....	4.00 Cu	Yes	Yes	Yes
AISI 304	0.06	1.75	0.50	18.00	10.00	....	....	....	Yes	Yes	Yes
AISI 309	....	1.75	0.50	25.00	12.00	....	....	....	Yes	Yes	...
AISI 309 Cb	0.08	1.75	0.50	25.00	12.00	....	0.80	....	Yes	...	...
AISI 310	0.08	1.75	0.50	25.00	20.00	....	....	....	Yes	Yes	Yes
AISI 310 Cb	0.08	1.75	0.50	25.00	20.00	....	0.80	....	Yes	...	...
AISI 316	0.08	1.75	0.50	16.00	13.00	2.50	....	....	Yes	Yes	...
AISI 316 Cb	0.08	1.75	0.50	16.00	13.00	2.50	0.80	....	Yes	...	...
AISI 317	0.08	1.75	0.50	18.00	13.00	3.50	....	....	Yes	...	...
AISI 317 Cb	0.08	1.75	0.50	18.00	13.00	3.50	0.80	....	Yes	...	...
AISI 321	0.08	1.75	0.50	18.00	12.50	....	....	0.50 Ti	Yes	...	...
B&W 15-15-N	0.15	1.75	0.50	16.00	15.00	1.25	1.00	1.50 W, 0.15 N_2	Yes	Yes	...
Timken 16-25-6	0.12	1.75	0.50	16.00	25.00	6.00	....	0.15 N_2	Yes	Yes	...
A-286	0.08	1.50	0.75	15.00	26.00	1.25	....	2.00 Ti, 0.20 Al, 0.30 V	Yes	Yes	...
Discaloy	0.08	....	....	13.50	26.00	3.00	....	1.60 Ti; 0.20 Al	Yes	Yes	Yes
Refractaloy 26	0.08	....	....	18.00	37.00	3.00	....	2.70 Ti, 0.50 Al, 20.00 Co	...	Yes	...
K42B	0.05	....	....	18.00	42.00	....	....	2.00 Ti, 0.60 Al, 22.00 Co	...	Yes	...
19-9-DL	0.30	....	....	19.25	9.00	1.25	0.40	0.30 Ti, 1.25 W	Yes	...	...
AISI 330	0.15	1.50	0.75	15.00	35.00	....	....	....	Yes	...	...
Nodular iron	3.25	0.25	2.25	....	....	....	....	....	Yes	...	...
Rex AA	0.70	0.30	0.30	4.00	....	....	....	18.00 W, 1.00 V	Yes	Yes	...
Peerless A	0.30	0.30	0.30	3.25	....	....	....	9.00 W, 0.25 V	...	Yes	...
Rex VM	0.90	0.30	0.30	4.00	....	8.00	....	1.90 V	...	Yes	...
Cyclops B4B	0.50	0.20	0.25	2.75	....	....	....	14.50 W, 0.50 V	Yes	...	...
Monel	....	....	....	....	67.00	....	....	30.00 Cu	Yes	Yes	...
"A" Nickel	....	....	....	....	99.4	....	....	....	Yes	...	...
Nimonic 80	....	....	....	21.00	75.00	....	....	2.44 Ti, 0.60 Al	...	Yes	...

Production Characteristics

Wrought Stainless Steel

Machinability • Hot and cold working
Forging • Cutting and shearing • Stamping
Deep drawing • Welding • Brazing
Soldering • Finishing

By Basil T. Lanphier
Metallurgist
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Reading, Pa.

FOR MANY applications of wrought stainless steel, selection is based on two factors: necessary degree of corrosion or heat resistance, and physical and mechanical properties. But a third factor—fabrication characteristics—can often be the critical influence determining the alloy to be used. Eventual cost of a part depends strongly on how well the alloy can be manufactured by the desired process. Since many of the stainlesses are designed for specific fabricating advantages, a working knowledge of these production characteristics can simplify selection.

The stainless alloys are generally defined as iron alloys containing 12 to 30 per cent chromium and zero to 20 per cent nickel. There are approximately 30 standard grades of wrought stainless, varying widely in characteristics. Additionally, a number of proprietary stainless alloys have been developed by different producers for specific fabricating requirements. However, for convenience, this discussion will cover only the standard types, which can be divided into three basic groups:

Group A—Martensitic Hardenable Steels: Contain chromium and carbon as principal alloying elements. Respond to heat treatment and can be hardened to provide a wide range of mechanical properties. They are magnetic. *Table* 1.

Group B—Ferritic Nonhardenable Steels: Comprises the chromium-iron alloys. Like Group A they are magnetic. They do not respond to heat treatment and are normally used in the annealed state where they exhibit their maximum softness, ductility, and corrosion resistance. Mechanical properties can be increased to a small extent by cold working. *Table* 2.

Group C—Austenitic Nonhardenable Steels: Chromium-nickel alloys which form the basis of this group offer a greater degree of corrosion resistance than the steels of Groups A and B. They are strong, tough, and ductile and, although they cannot be hardened by heat treat-

Table 1—Group A—Martensitic Stainless Steels

AISI Type No.	Carbon (per cent)	Chromium (per cent)	Other Elements (per cent)
403	0.10	12.50	....
410	0.10	12.50	....
414	0.10	12.50	2.00 Ni
416	0.10	13.00	0.25 Si
420	0.30	13.00	....
420F	0.30	13.00	0.25 S or Se
431	0.15	16.00	2.00 Ni
440A	0.70	17.00	....
440B	0.85	17.00	....
440C	1.10	17.00	....
440F	1.10	17.00	0.25 S or Se

Nominal analyses; refer to AISI specifications for composition limits.

Table 2—Group B—Ferritic Stainless Steels

AISI Type No.	Carbon (per cent)	Chromium (per cent)	Other Elements (per cent)
405	0.07	12.50	0.20 Al
406	0.10	13.00	3.50 Al
430	0.10	17.00	....
430F	0.10	17.00	0.25 S or Se
442	0.30	20.00	....
443	0.15	20.00	1.00 Cu
446	0.30	27.00	0.15 Ni

Nominal analyses; refer to AISI specifications for composition limits.

ment, they can be appreciably strengthened by cold working. They are nonmagnatic. *Table* 3.

Group A — Martensitic (Hardenable) Stainless Steels: All alloys of this group are hardenable by heat treatment. Types 403, 410, 414, 416 and 431 respond to heat treatment much like the SAE alloy steels containing 0.30 per cent carbon (SAE 3130, 4130, etc.). Intermediate properties can be obtained by varying the tempering or drawing treatment, or the steels can be used annealed since they do not have to be hardened for maximum corrosion resistance.

Types 420, 440A, 440B and 440C are more nearly comparable to tool steels. Because of their high carbon content they must be fully hardened for maximum corrosion resistance; they should not be used annealed.

Fabrication of the martensitic steels, as with all stainless steels, can be accomplished without difficulty when the proper allowances are made for their greater strength. They can be forged, hot rolled, cold rolled, cold drawn, formed, bent, upset, coined, machined, and welded or brazed. However, each grade has certain characteristics that expand or limit its response to a given fabricating technique.

Type 410, being the base analysis of the group, is balanced to contain just sufficient chromium and carbon for stainlessness and moderate mechanical strength. This steel can be readily hot worked—forged, headed, riveted, and upset. It is stiffer and stronger than mild steel at the temperature used for forging and consequently requires more blows or a heavier hammer. Because of the air hardening tendencies of the steel, large or intricate forgings should be cooled slowly from the forging temperature to prevent cracking. Small forgings can be air cooled.

In the annealed condition type 410 can be cold headed, blanked, formed or drawn. Its machinability is generally comparable to the SAE alloy steels containing 0.40 per cent carbon, although when dead-soft annealed, it is tough and draggy. It machines better at higher hardness and can be machined at hardnesses up to 34 Rockwell C.

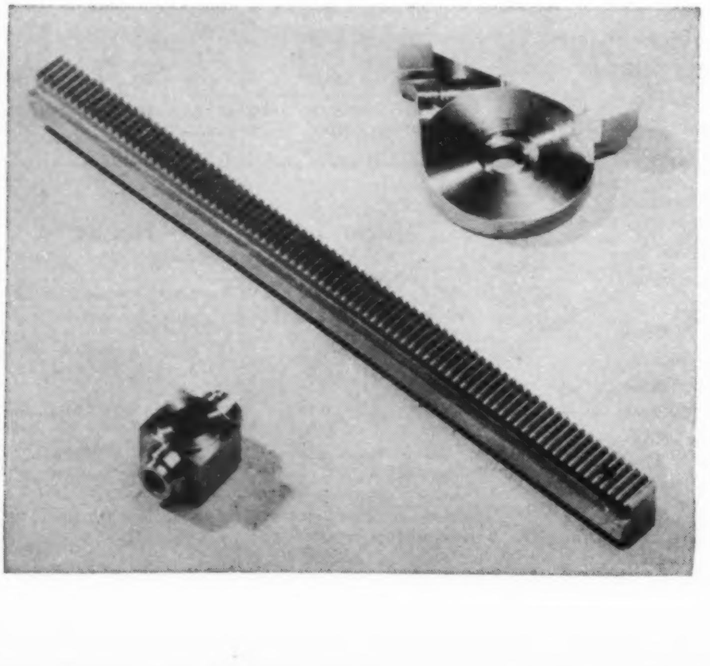
Type 410 can be satisfactorily welded by any of the arc or resistance welding techniques. In arc welding it should be preheated and welded with filler rods of similar analysis. If preheating is not possible, better results can be secured by using austenitic stainless (Group C) electrodes. Type 410 is usually annealed after welding to restore full ductility to the weld area.

Type 403, the turbine quality steel, is a prime grade of type 410. It has the same production characteristics as type 410.

Type 416 is a free-machining modification of the 410 analysis. The addition of small amounts of sulphur or selenium markedly improves the machinability of the steel. It can be hot worked readily but is somewhat more tender than type 410 in this respect. It is not recommended for severe cold forming applications, welding, brazing, or for vessels that must be pressure-tight. It is used in all applications where type 410 normally would be used but ease of machinability is an important factor. It is well suited for use in automatic screw machines. Based on tonnage consumed, type 416 is the most important steel of Group A.

Type 414 is commonly produced in the form of tempered cold-rolled strip for the manufacture of springs, tempered rules, scraper knives and similar products requiring hardnesses in the range of 43-48 Rockwell C. This steel withstands a degree of forming unusual for this high hardness. In the annealed condition, type 414 can be cold formed, blanked, and headed, although allowance must be made for its high annealed hardness.

Type 431 is designed to provide the maximum corrosion resistance consistent with the hardenable characteristics of the Group A steels. The mechanical properties, heat treatment, and fabricating qualities of type 431 are similar to those of type 414.



Dimensions on precision parts for a military bombsight are held to tolerances of ± 0.0001-inch. Stainless is used for corrosion resistance, wear resistance and a high strength-to-weight ratio. All parts have a high ratio of labor to material cost. To keep rejects to a minimum, type 416 stainless is used for easy machinability and long tool life. One small piece contains less than 1 cent's worth of steel, but is listed as an $8.00 cost item

Type 420 is the original stainless steel. Fabrication of this steel requires attention. Forging or hot forming is readily accomplished, provided adequate precaution is taken to cool the part slowly from the forging heat to prevent cracking due to air hardening. Furnace cooling is preferred.

When annealed for maximum softeness, type 420 can be moderately cold formed, headed, or hobbed. It machines like a high-carbon tool steel. A modified analysis containing small amounts of sulphur or selenium, and designated as type 420 F, is available where better machining properties are needed.

Type 420 is seldom welded because of its strong air-hardening tendencies. This steel is never used in the annealed condition because it requires hardening to bring out its corrosion resistance. Since it is more difficult to fabricate than the lower carbon type 410, it should be used only in applications which demand the additional hardness and strength.

The type 440 steels offer the maximum hardness obtainable in the entire family of stainless steels. Three grades are available containing varying amounts of carbon. As carbon content is increased, hardness obtainable by heat treatment increases, and toughness and workability of the steel decrease. These steels must be fully hardened for corrosion resistance; accordingly, three carbon ranges are offered to provide the optimum combination of hardness, toughness and workability for all applications.

Generally, the 440 steels are somewhat more difficult to fabricate than type 420; however, all operations can be done on a commercial basis where the extra hardness and wear resistance are required. These steels can be forged, hot headed and upset, but as with type 420, they must be cooled slowly from the forging heat to prevent cracking. They respond to simple cold-forming operations and when annealed for maximum softness, can be headed and upset. The lower carbon grades are easier to form.

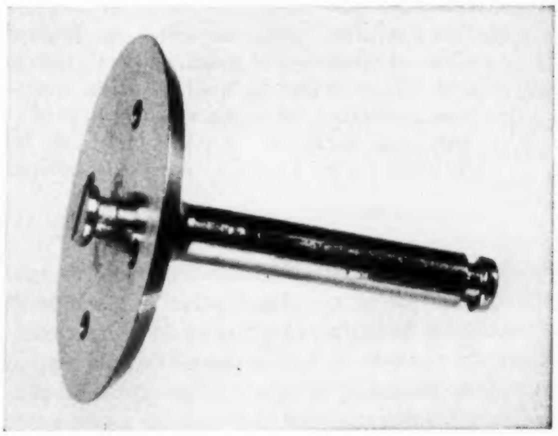
Table 3—Group C—Austenitic Stainless Steels

AISI Type No.	Carbon (per cent)	Chromium (per cent)	Nickel (per cent)	Other Elements (per cent)
301	0.12	17.00	7.00	......
302	0.12	18.00	9.00	......
302B	0.12	18.00	9.00	2.50 Si
303	0.12	18.00	9.00	0.25 S or Se
304	0.07	19.00	10.00	......
304L	0.03 max	19.00	10.00	......
305	0.12	18.00	12.00	......
308	0.07	20.00	11.00	......
309	0.15	23.00	13.00	......
310	0.20	25.00	20.00	......
314	0.20	25.00	20.00	2.50 Si
316	0.08	18.00	12.00	2.50 Mo
316L	0.03 max	17.00	12.00	2.50 Mo
317	0.08	19.00	12.50	3.50 Mo
321	0.07	18.00	10.00	0.40 Ti
347	0.07	18.00	11.00	0.70 Cb + Ta

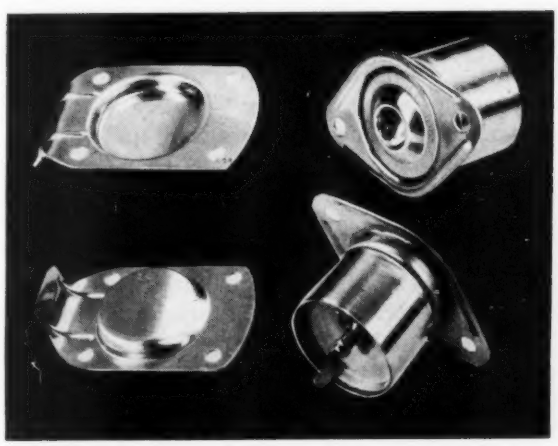
Nominal analyses; refer to AISI specifications for composition limits.

These steels, because of their high carbon content, machine about the same as the high-speed tool steels. Free-machining analyses are available.

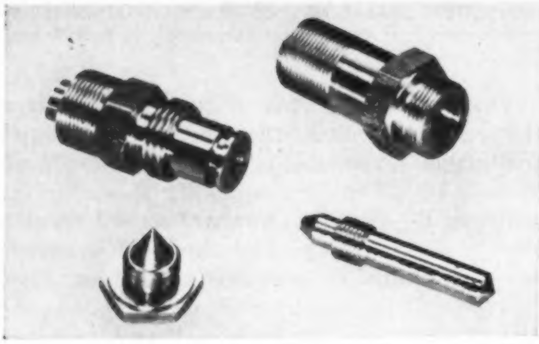
Group B—Ferritic (Nonhardenable) Steels: The steels of this group, like those of Group A, are basically alloys of iron and chromium. However.



Stainless valve for fuel-return regulator check is one of a variety used in refrigeration, heat control, carbonation and similar applications. These valve parts must not leak under pressure. So extra-fine finishes on critical surfaces are required, and some surfaces are machined to a 5 or 10 microinch finish with tolerances as close as 0.0005-inch. Type 303 stainless is used to get necessary corrosion resistance along with easy machinability and fine finish. On many parts the finish as-machined is good enough to eliminate subsequent grinding and polishing



Material for this automobile door safety lock had to be economical to fabricate, provide high strength, corrosion resistance and a bright finish. Cold-rolled steel, chrome plated, was unsuccessfully tried. Type 430 stainless was found to have the necessary drawing qualities. Strip gage is 0.025-inch; width is 2½ inches



Needle-valve parts are used to control flow of compressed gases. Specifications call for a stainless with positive corrosion resistance, strength and eye appeal—and tolerances of ±0.001-inch on all finished parts. Type 303 has been selected

in the ferritic steels, the element carbon is controlled to the lowest practical value in each steel to minimize its harmful effect on corrosion resistance and to provide a softer, more ductile metal. Further, the lowering of the carbon content produces steels which are not subject to appreciable hardening when cooled from high temperatures. This nonhardening tendency is of particular advantage in the fabrication of these steels by processes which involve heating, as for example, in hot working or welding.

The ferritic steels do not respond to hardening by heat treatment; accordingly, the mechanical properties available are limited when compared to the martensitic steels of Group A. Normally used in the annealed condition, these alloys offer greater strength and slightly better ductility than ordinary carbon steels.

Strength of these steels can be moderately increased by cold working. Tensile strengths to 125,000 psi are obtainable in strip, wire, and similar sections which can be drastically cold worked.

The ductility and relative softness of the ferritic grades permit fabrication by practically all of the standard techniques. Hot working and forging operations are somewhat simpler than for the martensitic steels since the danger of cracking due to air hardening is eliminated.

Similarly, these steels can be welded with greater ease; however, the higher chromium steels of the group are susceptible to grain coarsening and embrittlement in the heat-affected zone of the weld and consequently they are normally annealed after welding to restore ductility. In heavy weld sections requiring the use of filler rods, it is common practice to use austenitic (Group C) electrodes to provide a tougher, more ductile weld bead.

The ferritic steels are readily cold formed by rolling, spinning, roll forming, bending, drawing, etc. They have a low rate of work hardening and a relatively high yield strength. This combination of properties encourages localized thinning or necking down under tensile stresses which requires that caution be exercised in cold forming operations that involve stretching, such as deep drawing. Machinability of these steels is generally comparable to that of type 410.

Type 405 is essentially a modified type 410 stainless. Carbon content is kept as low as is commercially possible, and a small amount of aluminum is added to completely suppress the hardening properties of the steel. It is designed for applications which involve welding but which cannot be annealed to restore ductility.

In type 406 the high percentage of aluminum performs several functions. In addition to suppressing hardenability, it contributes greatly improved oxidation resistance and sharply increases the electrical resistivity of the metal. Type 406 is used almost exclusively as a low-cost electrical resistance element for service at temperatures up to 1600 F.

Type 430 stainless steel is the most important and most versatile steel of the group. Although one of the first types of stainless steels commercially manufactured, it has only recently come into prominent use. Corrosion resistance of type 430 is exceptionally good, approaching that of the chromium-nickel steels of Group C.

Type 430 is well adapted to the various fabricating procedures. Forging of this steel presents no problems. Although stronger and stiffer than mild steel at forging temperature, it is extremely malleable, and can be forged to the most complex shapes. It can be hot worked over a relatively broad temperature range; however, precautions must be taken to avoid overheating and grain coarsening. Forged parts can be air cooled without danger of cracking.

The 430 analysis is particularly suited for cold forming operations, such as spinning, roll forming, blanking, stamping, etc. Practically all of the intricate moldings used in automotive trim are cold-formed type 430 strip steel. Deep-drawn parts can also be made successfully. Its drawing characteristics are somewhat like those of mild steel. Drawing should be accomplished in gradual stages, and emphasis placed on die design to avoid stretching of the metal. In this respect, the steel does have some limitations when compared to the tougher, more ductile austenitic steels of Group C. With proper consideration of these differences, equally satisfactory results can be obtained.

Weldability is good although welded structures should be annealed to restore full corrosion resistance and ductility. A modified analysis containing titanium, however, has simplified this problem.

Type 430F is the free-machining counterpart of the foregoing type. Its ductility and formability are not quite as good as the standard type 430 and it is generally reserved for parts which require extensive machining. As with all free-machining stainless steels, it is not recommended for fabrication by welding.

Type 442 is generally classed as a heat-resistant steel and is widely used for scale-resisting purposes.

Type 443 offers several advantages over the companion alloy, type 442. The copper content provides additional corrosion resistance in certain chemicals. It has excellent oxidation resistance. Fabricating qualities are similar to those of the 430 analysis; however, some allowances must be made for the lower ductility of this steel.

Type 446 is a corrosion and heat-resisting steel with the maximum amount of chromium consistent with commercial malleability. Nitrogen is intentionally added to inhibit grain coarsening and embrittlement at elevated temperatures.

This alloy is principally used for its excellent oxidation resistance at temperatures up to 2000 F. The low ductility associated with the chromium content of this steel introduces fabricating difficulties, particularly in cold forming or welding operations.

Group C—Austenitic (Nonhardenable) Stainless Steels: The austenitic or chromium-nickel stainless steels comprise a group of iron alloys containing from 16 to 26 per cent chromium and from 6 to 22 per cent nickel. These steels are noted for high strength accompanied by exceptional toughness, ductility, and formability. As a class, the austenitic grades exhibit considerably better corrosion-resisting qualities than the martensitic or ferritic steels. Further, they have excellent strength and oxidation resistance at elevated temperatures.

Relative proportions of chromium and nickel exert a strong influence on the mechanical properties and workability of these steels, and are controlled in types 301, 302, 304, and 305 to produce a distinct series of alloys. In general, steels with a high chromium-to-nickel ratio (for example, type 301) will harden rapidly when cold worked and are suited for high-strength applications. Conversely, those with a low chromium-to-nickel ratio (for example, type 305) are more workable and are designed for fabricating advantages.

The chromium-nickel stainless steels as a group exhibit a higher level of corrosion resistance than is shown by the straight-chromium steels. The difference is principally one of degree; however, there is a wide variety of chemicals which can be handled only by the austenitic stainless steels. The 18-8 steels of the group, types 301, 302, 303, 304, 304L, 305, 321 and 347, show the same general order of corrosion resistance. There is some gain with increased alloy content but the selection of these steels normally depends on mechanical requirements or fabricating techniques.

Chromium-nickel steels, like the ferritic steels of Group B, cannot be hardened by heat treatment. They do, however, work harden rapidly when cold worked and can be appreciably strengthened in this manner. This response to cold working is a function both of analysis, as previously discussed, and of degree of cold deformation. As might be anticipated, parts with large cross sections cannot be strengthened in this way, whereas extremely fine wire or strip which can be drastically cold drawn or rolled can be processed to tensile

Table 4—Hot Working and Forging Characteristics

AISI Type No.	Forging	Heading	Upsetting	Look out for . . .
302, 304	Good	Good	Good	Intergranular corrosion[2]
303	Good	Good	Good	Intergranular corrosion[2]
305	Good	Good	Good	Intergranular corrosion[2]
316, 317	Good	Fair	Good	Intergranular corrosion[2]
321, 347	Good	Good	Good	....
403, 410	Good	Good	Good	Air hardening
414	Good	Note 1	Fair	Air hardening
416	Good	Good	Good	Air hardening
420	Good	Good	Good	Air hardening
420F	Good	Fair	Fair	Air hardening
430	Good	Good	Good	Grain growth
430F	Good	Good	Good	Grain growth
440A	Good	Fair	Fair	Air hardening
440C	Fair	Fair	Fair	Air hardening
443	Good	Good	Good	....

[1]Slight to fair. [2]Quench from at least 1900 F.

Table 5—Cold Working and Forging Characteristics

AISI Type No.	Forging	Heading	Upsetting	Coining	Roll Threading	Hobbing
302, 304	Good	Good	Good	Good	Good	Poor
303	Poor	Good[1]	Slight	Fair	Good	No
305	Good	Good	Good	Good	Good	Fair
316, 317	Fair	Fair	Good	Fair	Good[4]	Poor
321, 347	Good	Good	Good	Good	Good	Poor
403, 410	Good	Good	Good	Good	Good	Good
414	Poor	Poor	Slight	Poor	No	No
416	Poor	Slight	Slight	Fair	Good	No
420	Slight	Good[2]	Fair[3]	Good[3]	Fair	Good[2]
420F	Poor	Fair[3]	Slight	Fair	Fair	No
430	Good	Good	Good	Good	Good	Good
430F	Poor	Slight	Slight	Fair	Good	No
440A	Slight	Fair	No	Good	No	Fair
440C	Poor	Fair	No	Poor	No	Fair
443	Good	Good	Good	Good	Good	Fair

[1]Specify for cold heading. [2]If specially annealed. [3]If properly annealed. [4]Good threads; poor tool life.

Table 6—Machining and Grinding

AISI Type No.	Machinability (Turning, sfpm)	Grinding (Ease)	Grinding (Magnetic?)
302, 304	40–85	Fair	No
303	85–120	Good	No
305	40–85	Fair	No
316, 317	40–85	Fair	No
321, 347	60–90	Good–Fair	No
403, 410	80–115	Fair	Yes
414	40–80	Good	Yes
416	110–140	Excellent	Yes
420	40–80	Fair	Yes
420F	80–110	Good	Yes
430	85–115	Fair	Yes
430F	120–150	Excellent	Yes
440A	40–80	Good[1]	Yes
440C	40–60	Good[2]	Yes
443	80–110	Fair	Yes

[1]If hardened. [2]If fully hardened.

strengths as high as 325,000 psi.

Increase in strength and hardness by cold working is, or course, accompanied by a reduction in ductility. However, even the most drastically cold-worked material retains sufficient ductility for many fabricating operations.

The excellent mechanical properties of the chromium-nickel steels greatly facilitate fabrication. These steels can be hot worked without difficulty and like the ferritic steels can be air cooled from forging temperature without danger of cracking. However, when heated in or cooled slowly through the temperature range of 800 to 1650 F, carbon in the steel precipitates in the grain boundaries as chromium carbide. This condition renders the steel susceptible to intergranular corrosion. Accordingly, parts which have been air cooled must be annealed by reheating to approximately 2000 F, followed by water quenching to restore full corrosion resistance.

This same condition is encountered when welding these steels. Strong, tough welds are easily obtained, using standard equipment and techniques, but the weld area is unavoidably heated to this

Table 7—Cutting and Shearing

AISI Type No.	Shearing (Cold)	Slitting	Sawing
302, 304	Good	Good	Fair
303	Good	Note 1	Good
305	Good	Good	Fair
316, 317	Good	Good–Fair[2]	Fair
321, 347	Good	Good	Good
403, 410	Good	Good	Good
414	Good	No	No
416	Good–Fair	Note 1	Good
420	Fair	Fair	Fair
420F	Fair	Note 1	Good
430	Good	Good	Good
430F	Good–Fair	Note 1	Good
440A	Fair	Fair	Poor
440C	Fair	Note 1	Poor
443	Good	Good	Fair

[1]Not usually available as strip or sheet. [2]Depending on hardness.

Table 8—Stamping and Deep Drawing

AISI Type No.	Blanking	Punching[1] (Perforating)	Forming	Embossing	Deep Drawing
302, 304	Good	Yes	Good	Good	Good
303	Good	Yes	No	Fair	Poor
305	Good	Yes	Good	Good	Good
316, 317	Fair[2]	Yes	Good	Fair[4]	Good
321, 347	Good	Yes	Good	Good	Good
403, 410	Good	Yes	Good	Good	Good
414	Good	Yes	No	Poor	Poor
416	Good	Yes	No	Fair	Poor
420	Good	Yes	Fair[3]	Good[3]	Poor
420F	Good	Yes	No	Fair	Poor
430	Good	Yes	Good	Good	Good
430F	Good	Yes	No	Fair	Poor
440A	Fair	Yes	Fair	Good	Poor
440C	Fair	Yes	Fair[3]	Poor	Poor
443	Good	Yes	Good	Good	Good

[1]Free-machining grades and chromium steels tend to punch well; chrome-nickel grades tend to drag at the break. [2]Requires high pressure. [3]If annealed. [4]Short die life.

Table 9—Forming, Swaging and Spinning

AISI Type No.	Press Brake Forming	Roll Forming	Swaging	Spinning[1]
302, 304	Good	Good	Good	Good
303	Poor	No	Slight	No
305	Good	Good	Good	Good
316, 317	Good	Fair[4]	Fair	Fair
321, 347	Good	Good	Good	Good
403, 410	Good	Good	Good	Good
414	Note 2	No	No	No
416	Poor	No	Slight	No
420	Good	No	Fair	Poor
420F	Poor	No	Slight	No
430	Good	Excellent	Good	Good
430F	Poor	No	Note 2	No
440A	Good[3]	No	Slight	No
440C	Poor	No	Slight	No
443	Good	Good	Good	Good

[1]Types 304 and 305 are best in the chrome-nickel group; straight chrome steels do not work-harden as rapidly as chrome-nickel steels. [2]Very slight. [3]In annealed condition. [4]If specially annealed.

Table 10—Welding, Brazing and Soldering

AISI Type No.	Brazing[1]	Soldering (Hard[1] and soft)	Fusion and Resistance Welding[1]
302, 304	Good	Good	Good
303	Poor	Poor	Weldable[2]
305	Good	Good	Good
316, 317	Fair	Good	Good
321, 347	Good	Good	Good
403, 410	Good	Good	Satisfactory[3]
414	Fair	Fair	Satisfactory[3]
416	Poor	Poor	Weldable[2]
420	Fair	Fair	Satisfactory[4]
420F	Poor	Poor	Weldable[2, 4]
430	Good	Good	Note 5
430F	Poor	Poor	Weldable[2]
440A	Fair	Fair	Fair[4]
440C	Fair	Fair	Fair[4]
443	Good	Good	Excellent

[1]Caution must be used to prevent intergranular corrosion, air hardening or grain growth caused by high heat. [2]With 308 coated rods; avoid atomic hydrogen. [3]Weld hardens on cooling. [4]Requires special welding procedures to prevent cracking due to air hardening. [5]Weld brittle below 200 F; should be annealed to obtain maximum toughness.

Table 11—Finishing Characteristics

AISI Type No.	Buffing[1]	Polishing[1] (Set-up wheels)	Tumbling (Ball burnishing)	Electrolytic Polishing
302, 304	Excellent	Excellent	Excellent	Excellent
303	Excellent	Good finish	Excellent	Note 2
305	Excellent	Excellent	Excellent	Excellent
316, 317	Good	Good	Good	Good
321, 347	Excellent	Excellent	Excellent	Good
403, 410	Excellent	Excellent	Excellent	Good
414	Excellent	Excellent	Fair	Good
416	Excellent	Good finish	Excellent	Note 2
420	Good	Good	Fair	Note 3
420F	Good	Good	Fair	Note 4
430	Excellent	Excellent	Excellent	Good
430F	Excellent	Good finish	Excellent	Note 2
440A	Good	Fair	Fair	Note 5
440C	Good	Fair	Fair	Note 5
443	Excellent	Good	Excellent	Good

[1]Slight tendency to "pin feather drag" on free-machining grades. [2]Good longitudinally; poor transversely. [3]Good if hardened; otherwise fair. [4]Good longitudinally if hardened; poor transversely. [5]Good if hardened.

critical range and must be subsequently annealed. The problem of intergranular carbide precipitation can be avoided by using types 304L, 316L, 321 or 347. The carbon in types 321 and 347 is "stabilized" by combining it with the carbide forming elements, titanium or columbium. In the case of 304L and 316L the problem of carbide precipitation is minimized by controlling the carbon content of the steel to very low levels (i.e., 0.03 per cent max).

Austenitic stainless steels are particularly suited for cold forming operations, using the recommended techniques. They can be deep drawn, spun, roll formed, blanked, perforated and cold headed without difficulty. The cold work hardening properties of these steels place some limit on the amount of cold forming which can be done. However, by selecting the steel with the proper rate of work-hardening, many of the most severe deep drawing and forming jobs can be accomplished without an intermediate annealing treatment.

Machining of the austenitic steels generally requires slower speeds than those used with the straight-chromium steels. Satisfactory results are obtained with the proper tool design and lubrication. Type 303, the free-machining grade, is recommended for parts which involve extensive machining.

Type 301 work hardens rapidly when cold worked and is designed for high-strength applications. Because of its relatively low alloy content, its corrosion resistance is not quite comparable to type 302. Type 301 is normally produced in the form of cold-rolled strip or sheet for structural components of aircraft, railroad cars, and truck bodies.

Type 302 is a general-purpose 18-8 alloy. It does not work harden as rapidly as type 301 and responds readily to drawing, forming, bending and upsetting operations. However, it can be materially strengthened by cold working and is frequently produced in cold-rolled strip and cold-drawn wire.

Type 303, generally manufactured in bar form is used for all parts that are fabricated by machining, grinding and polishing. It is not recommended for welding nor for pressure-tight fittings.

Type 304 is a low-carbon modification of type 302. It is a better material for welding and in thin sections can be welded with less trouble from intergranular corrosion. The corrosion resistance and formability of this analysis is somewhat superior to that of type 302.

Type 304L is a *very* low carbon modification of the standard type 304. Carbon content is held to 0.03 per cent maximum so the steel can be welded in both thin or heavy sections without danger of intergranular corrosion.

Type 305, the deep-drawing stainless steel, has a balanced analysis designed for maximum formability. Excellent ductility, coupled with an extremely low rate of work hardening, renders this steel suitable for the most severe deep-drawing and spinning operations.

Type 308, containing higher chromium and nickel than the typical 18-8 analyses, is most commonly produced in wire form for the manufacture of general-purpose welding electrodes. It is used for the welding of the nonstabilized stainless steels, types 301, 302, 304, and 305. Type 308 welding rod is also used in the welding of the martensitic and ferritic grades, and in the repair welding of mild steel and cast iron where tough ductile welds are required.

Types 309 and 310 are generally classed as heat-resisting steels. Both grades can be forged, hot formed, cold formed and welded without difficulty; however, they do require closer control of fabricating procedures because of their higher alloy content. Available in the lower carbon analyses, designated as 309S and 310S these grades are useful in chemical service. They resist the same general types of corrodents as type 304 but provide a greater margin of safety and can be used at higher concentrations and temperatures.

Type 314, a high-silicon variation of type 310, is particularly resistant to carburizing atmospheres commonly encountered in heat-treating equipment.

Type 316 is considered the most corrosion resistant of all of the standard stainless steels. It is used in many applications where the straight-chromium-nickel steels have shown borderline resistance.

Type 316L is a *very* low carbon modification of the standard type 316. Carbon content of this grade is held to 0.03 per cent maximum to minimize the problem of intergranular corrosion. The steel is designed for fabrication by welding.

Type 317 is a modification of type 316, containing higher molybdenum. This steel has been used in several special applications where the resistance of type 316 was found inadequate.

Types 321 and 347, the stabilized stainless steels, are so called because they contain elements which combine with carbon to form stable titanium or columbium carbides. As previously discussed, this is an important function, for it prevents the harmful formation of chromium carbides during welding or when exposed in the temperature range of 800 to 1650 F. Unlike the straight-chromium-nickel types, their corrosion resistance is not impaired by welding.

Both these steels are recommended for parts which are to be used in the as-welded condition, and for equipment operating at temperatures up to 1700 F. At elevated temperatures, these grades are appreciably stronger than the other steels of the group, with the exception of type 316.

Of the two, type 347 offers several advantages; its corrosion resistance, equal to that of type 304, is somewhat better than that of type 321. Further, in welding, the columbium is retained in the weld metal, whereas with type 321 some of the titanium is lost due to oxidation. Accordingly, type 347 welding electrodes are required for the welding

of type 321. For these reasons, type 347 has been used almost to the exclusion of type 321 in this country.

Relative Production Characteristics: In the previous section, certain fabrication techniques for each of the major stainless alloys have been covered in some detail. For easy comparison between the types, however, the following tables may be of assistance:

Table 4—Hot working and forging characteristics
Table 5—Cold working and forging characteristics
Table 6—Machining and grinding
Table 7—Cutting and shearing
Table 8—Stamping and deep drawing
Table 9—Forming, swaging and spinning
Table 10—Welding, brazing and soldering
Table 11—Finishing characteristics

These comparisons are very broad but give indications of the type of production methods best suited to each alloy. Specific recommendations, of course, must be made in the light of all pertinent factors—and further, more detailed investigation is usually necessary. But time can be saved by preselection of suitable alloys during the design stage.

Production Characteristics

Gray Iron

Castability • Section sensitivity • Machinability
Finishing • Specifications

By C. F. Walton
Technical Director
Gray Iron Founders Society Inc.
Cleveland, Ohio

TODAY, the name "gray iron" means a whole series of alloys with a wide range of properties. Characteristics commonly attributed to gray iron are not equally present in all grades. In many applications considerable advantage is obtained by selecting the type of iron which best fulfills the requirements of the job.

For example, some advantage in machinability is sacrificed when very high tensile strength is specified. The design engineer should establish what properties he must have, those which are desirable, and those which are unnecessary from an economic standpoint. Also, all castings cannot be made in all classes of gray iron. There are limiting factors such as casting weight and section thickness, *Table* 1, but for each casting there is some class of gray iron which is *most* suitable.

Gray iron is one of the most easily cast alloys, and thus offers all the advantages of the casting process. These advantages are well known, but might well be reiterated.

The casting process allows the designer extreme freedom of shape. Tapered sections, heavily blended fillets, nongeometric curves and rounded corners offer few problems. The foundry is a primary producer from basic raw materials, so order lead time is minimized. Availability is also important; there are over 2000 gray iron foundries in the United States in virtually every industrial area.

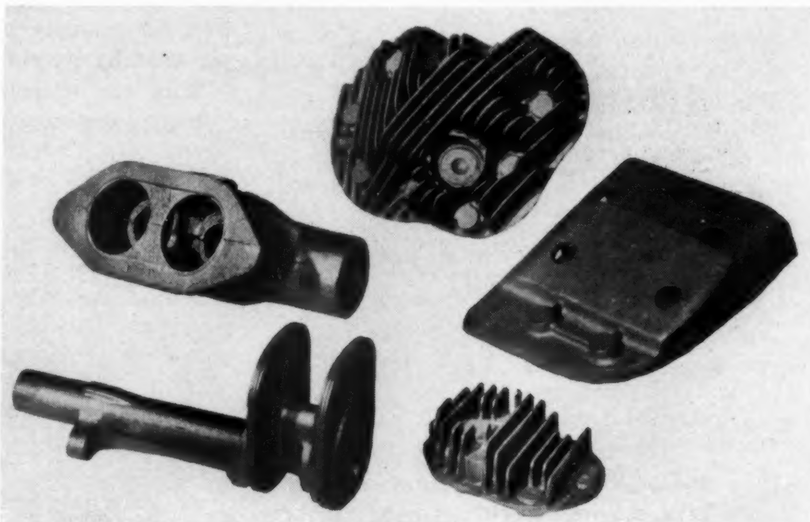
Castability: The castability of an alloy is the ease with which the alloy can be used to make commercial castings. It is a summation of the alloy's tendency to contribute to, or alleviate, common foundry problems of metal fluidity, solidification shrinkage, hot tearing, warping, cleanliness, etc.

Table 1—Minimum Wall Thicknesses for Gray Iron Castings

Class	Usual Minimum Thickness* (in.)	Class	Usual Minimum Thickness* (in.)
20	⅛	40	½
25	⅛	50	½
30	¼	60	¾
35	⅜		

*Particular castings are possible below this range, depending on casting design.

The lower ASTM class grades of gray iron have very little if any solidification shrinkage (not the same as patternmaker's shrinkage). The high-class grades have one-half to two-thirds the solidification shrinkage of other ferrous alloys. Molten gray iron is very fluid. It can be readily poured into thin section or complex castings of even large size. Hot tears are virtually nonexistent in all but the most exceptional castings. Freedom from these difficulties is mainly provided by the graphite in the alloy. This excellent castability allows great freedom in design and more efficient production.



Castability of gray iron is shown by parts with thin webs and complex coring. Parts are automotive castings: a thermostat housing, top left; an oil pump, bottom left; and three cylinder heads

Section Sensitivity: Mechanical properties of metal change as thickness or mass change. A heavy metal section generally has a coarser grain size and lower hardness than a light section of the identical material, primarily due to slower cooling rate. Although this is true of virtually all commercial materials, whether they are cast, rolled or forged, gray iron is particularly section sensitive. A decided change in the cooling rate can materially change mechanical properties. An example of difficulty from this effect would be a large machine base with heavy (4 by 6-inch) ways and a light (¼-inch) skirt. It would be most difficult for a foundry to cast a fine-grained wear-resisting iron in the ways without the thin skirt becoming so hard as to be unmachinable and subject to cracking. In borderline cases certain special foundry practices may be employed to produce satisfactory castings, but excessive variation in mass is to be avoided in a casting. Section differences of four or five-fold (i.e., ¼ to 1 inch or 1 to 5 inches) are usually routine if the sections are well blended together with tapered or generous fillets.

Machinability: As-cast gray iron has good machinability, but when annealed, machinability equals or excels that of any other ferrous material, and approaches the machinability of yellow brass. Machinability curves for various classes of gray iron and cutting speeds are given in *Fig.* 1.

Finishing: Virtually all standard methods of finishing can be used on gray iron, both metallic and nonmetallic. It is an excellent base for vitreous or porcelain enamel as well as paints, lacquer and organic enamel. It can be coated with nonferrous

Comparative Characteristics of Gray Irons

ASTM Class

20	25	30	35	40	50	60

←	→
Better machinability	Higher strength
More vibration absorption	Increased wear resistance
Better castability	Smoother finish
Thinner casting sections	More uniformity of properties in heavy sections
Better heat shock service	Higher rigidity
	Lower elevated-temperature creep

→ Best availability (classes 30 or 35) ←

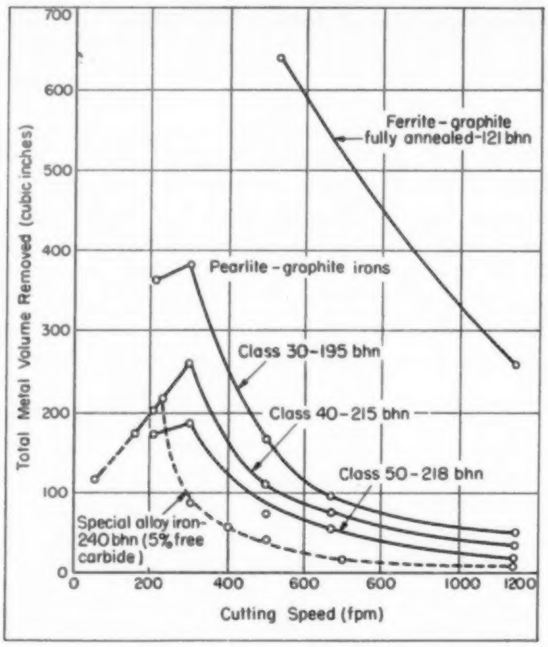
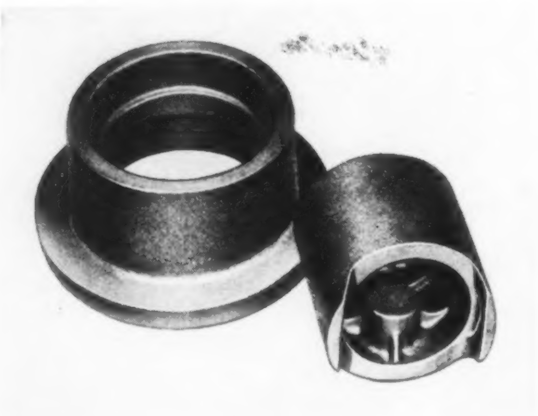


Fig. 1—Relative machinability of several classes of gray iron. Tool wear is the criterion limiting the volume of metal removed



Bearing cage and piston used in earth-moving machinery are cast in gray iron to obtain a smooth, dense, nonporous surface after machining

metals by either hot dipping or electroplating.

Specifications: Unfortunately, it is difficult to write purchase specifications for gray iron castings that clearly state all requirements and details.

Their manufacture is more of a service than the production of a commercial commodity. Quality depends primarily on the ability and integrity of the casting supplier. For metallurgical requirements, use of standard specifications such as those of ASTM or SAE is best whenever possible. Specifications by chemical analysis are to be avoided. Properties needed in the casting should be specified, leaving the foundryman to determine how best to obtain them. As with any other material, excessively close or unnecessary specifications increase cost and restrict the number of available sources of supply.

The various types of gray cast iron are not amenable to simple classification or specification by chemical analysis. Reason is that there are other factors in the manufacture of gray iron which are equally as important as the chemical analysis. These other factors vary among foundries, and there are no established standards for them. Even the easily determined values of routine chemical analysis are not in themselves fully significant. Distribution of graphite (graphitic carbon) in gray iron, for example, is equally as important as actual per cent by weight.

With the exception of casting applications involving corrosion resistance or elevated temperatures, the designer is not concerned with chemical analysis. He should establish purchase specifications on the basis of mechanical properties actually required. For example, a wear application may be specified simply on the basis of a minimum hardness, and possibly a required microstructure, with an addition of a maximum brinell hardness requirement if the part is to be machined.

The most commonly used specifications for gray iron iron are those of ASTM, as contained in specification A48-48. This basic specification is also used by many other societies, such as SAE, API, ASME and AAR. It lists seven classes of gray iron, based upon tensile strength. Class 20 has

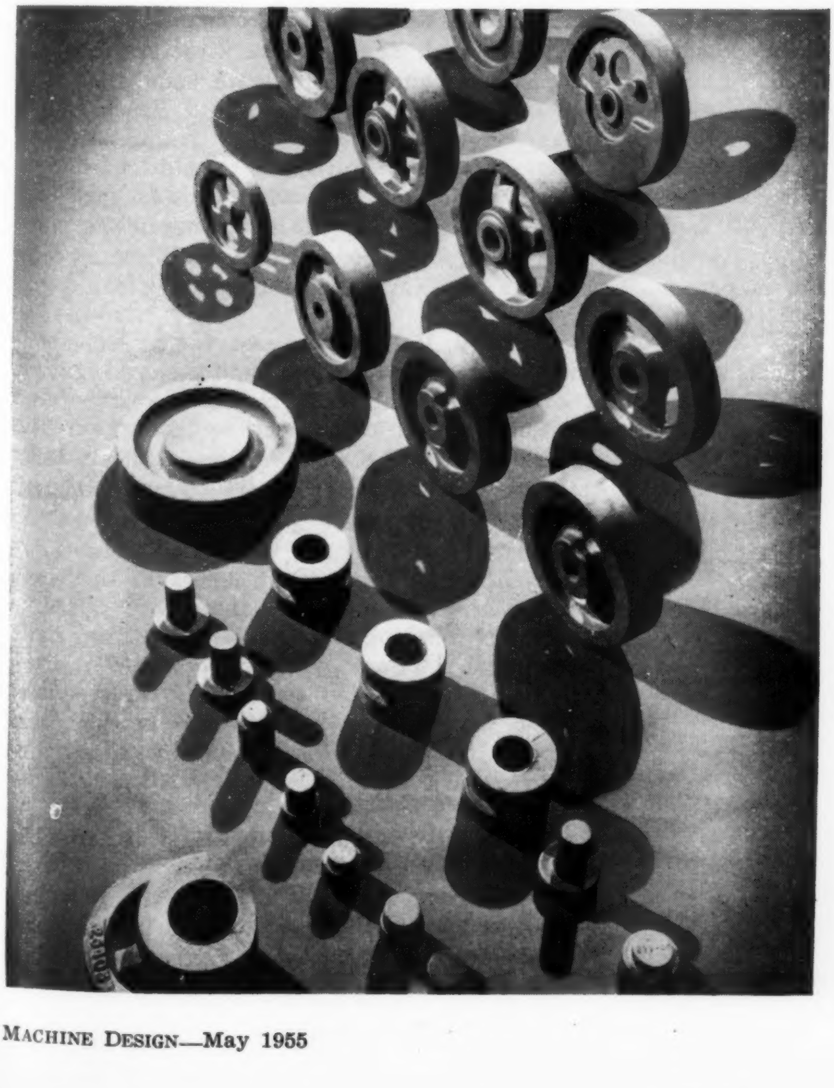
Gray-iron crankshaft for an air-compressor assembly. Castings are made by the permanent-mold process (similar castings are also made by shell molding). They are annealed to provide free machinability and prevent distortion or warping after machining

a minimum tensile strength of 20,000 psi; class 60, a 60,000 psi minimum; etc. ASTM specification A159-49T is primarily intended for automotive castings. This specification is also identical with that of SAE and contains special grades for brake drums and clutch plates.

One may ask why gray irons are classed on the basis of tensile strength when other properties can be more important to the design engineer. The fact is that the tensile strength is always somewhat less than shear strength, and much less than the compression strength. Thus, these latter properties will always exceed the tensile strength. An accurate value for yield strength in gray iron (and several other engineering materials) is difficult to determine in the routine tensile test, and using it as an inspection procedure would be complex or involve considerable personal judgment. Yield strength for gray iron is actually quite near the tensile strength because of the absence of ductility as commonly measured.

Close co-operation with the foundry can provide assistance in establishing an economic balance between what is desired and what may be commercially feasible. This practice has been the rule for years in many companies with their own foundries. The idea is becoming more common in inter-company relations when the designer and foundry are under separate management.

Above — Permanent-mold gray-iron castings are used in this refrigeration - compressor cylinder block to obtain a dense, nonporous structure capable of holding liquids and gases under pressure. For smooth finish, castings are annealed for maximum machinability



Gray-iron gear blanks provide necessary strength in a low-cost part cast close to final shape

Production Characteristics

Malleable Iron

Castability • Tolerances
Machinability • Standards

By James H. Lansing
Technical and Research Director
Malleable Founders' Society
Cleveland, Ohio

MALLEABLE iron is known for three major characteristics: (1) ductility and impact resistance, (2) castability, and (3) machinability. These attributes are prime reasons for the use of about a half-million tons of malleable castings in the automotive industry alone.

Standard malleable iron specifications are of two grades, shown in *Table* 1. For extra wear resistance, hardness and strength, and somewhat lower ductility and machinability, pearlitic malleable iron, *Table* 1, may be used. Both types will be covered in this article, with main accent on standard malleable.

Malleable Iron Production: All malleable castings start as white cast iron, with all the carbon in the combined (iron carbide) form. The castings are first heat treated at about 1600 F for a number of hours. At this temperature the hard iron carbides are broken up. Then, at a temperature of about 1300 F, there is another holding period during which all the remnants of pearlite are decomposed. The resultant structure is tough but easily machined ferrite, with nodules of temper carbon interspersed throughout. In this form the carbon does not detract from the strength and toughness of the metal but facilitates machining. Casting strains are eliminated by this heat conversion process. Also, since holding periods are relatively long, the conversion takes place as completely in the heavy as in the light sections.

Table 1—Malleable Iron Specifications

ASTM or SAE Grade	Tensile Strength (1000 psi, min)	Yield Point (1000 psi, min)	Elongation (% in 2 in., min)	Typical Hardness Range* (bhn)
Standard Malleable				
32510	50	32.5	10	......
35018	53	35	18	......
Pearlitic Malleable				
43010	60	43	10	163-207
48005	70	48	5	179-228
53004	80	53	4	197-241
60003	80	60	3	197-241
70002	90	70	2	241-285

*Not a specification requirement.

Castability: Malleable, as cast, has a carbon content of close to 2.5 per cent and a silicon content of over 1 per cent. Both elements contribute to the fluidity—and consequent castability—of the metal. For instance, small detachable chain links are cast with section diameters of approximately $\frac{1}{16}$-inch.

Malleable iron may be cast in sections varying from 2 to ¼-inch in thickness in the same casting. An example is an automotive differential carrier weighing some 20 pounds. It may have bearing-seat sections which incorporate a 1¼-inch cube of metal, but some of its wall sections and ribs may not be over ½-inch in thickness. A mortar foot casting, *Fig.* 1, also illustrates light-section castability.

Machinability: Machinability rating of malleable iron is high. Based upon cold-rolled or cold-drawn bessemer screw stock as 100 per cent, a rating of 120 per cent has been established for standard malleable iron. A malleable differential case before and after machining, *Fig.* 2, shows typical

Fig. 1—Light-section castability of malleable iron is shown by this mortar-foot casting

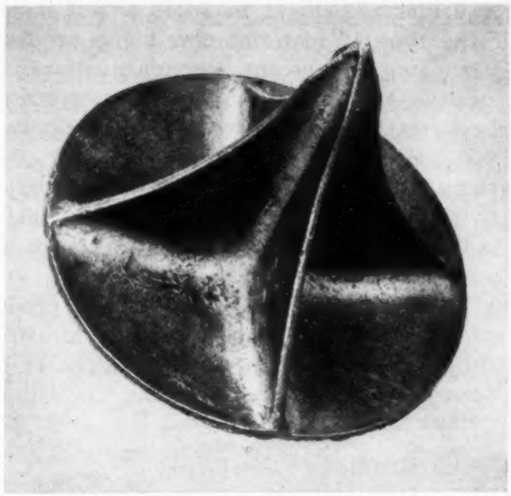


Fig. 2—Typical machining on a malleable-iron differential case. Metal is removed to a depth of 0.015-inch on the 7⅝-inch diameter flange, which is turned at 241 sfpm with 0.0115-inch feed per revolution and 0.010-inch depth of cut. Production totals 127 pieces per hour with carbide tools, and tool life averages 18 to 20 hours per grind

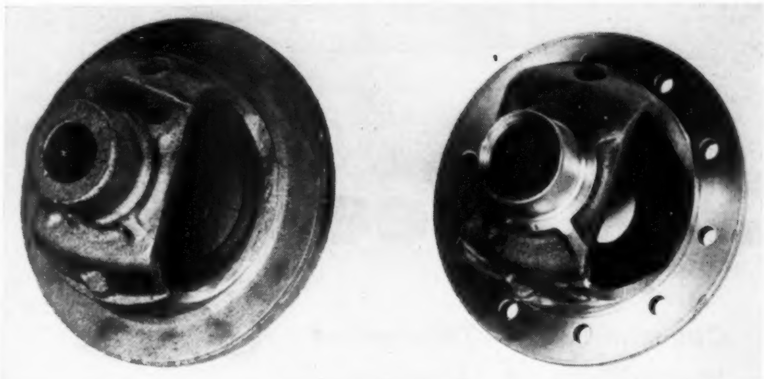
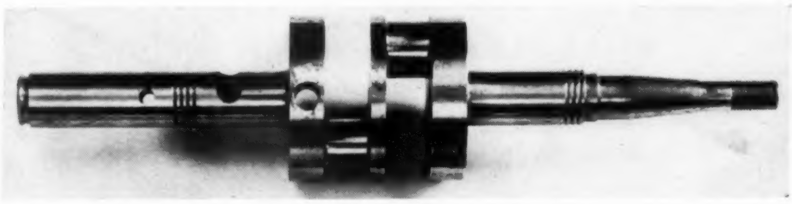


Fig. 3—Small engine crankshaft made of pearlitic malleable iron, a higher-strength material than standard malleable



machining operations.

Surface Finish: The original metal is usually poured at relatively low temperatures. Because of the metal's chemical composition and temperature, it does not contain occluded gases. Thus, castings can be made in relatively fine sand, resulting in excellent surfaces. Since castings are protected by containers or controlled atmospheres during the anneal or heat-conversion process, they are free from scale.

Draft and Tolerances: Some draft allowance is necessary to permit smooth removal of a pattern from the mold, this in turn contributing to the production of a smooth casting. For production patterns the draft may be as little as 1/64-inch per inch, less than 1 degree. It is possible to coin press malleable castings to close tolerances.

Uniformity: Casting of some metals may cause segregation, varying amounts of combined carbon and varying mechanical properties, depending upon the thickness of section and/or rate of cooling. Thus, when sections of widely varying thickness are included in one part, varying properties may exist in different areas. In the case of malleable iron, however, carbon is originally all in combined form, and is completely converted to free temper carbon by the annealing process. Minor decarburization occurs at the surface but, with this exception, the structure of malleable iron is uniform throughout, in both light and heavy sections.

Cost Factors: Original white-iron castings are produced in green (unbaked) sand molds, easily made and shaken out. In the original white-iron state, while the castings are brittle, gates, feeders and risers are easily broken from the casting without the use of cutting torches. Also, light fins can be trimmed (broken) from the casting. All of these factors contribute to low production cost.

Pearlitic Malleable Iron: Minimum pearlitic ten-

sile test values are shown in *Table* 1. But indicative of the type of material now being produced in the industry are recent recommendations for new tentative ASTM values. They range from the highest elongation grade, with minimum values of 65,000 psi tensile strength, 45,000 psi yield strength and 10 per cent elongation, to the highest strength grade, with minimum values of 100,000 psi tensile strength, 80,000 psi yield strength and 2 per cent elongation.

With increased hardness, the pearlitic product does not machine quite as easily as the standard, but still possesses excellent machinability. It has a machinability rating of 80 to 90 per cent.

Providing an excellent bearing surface, pearlitic malleable is used without bronze bushings in automotive-engine valve rocker arms. Also, in this application, its adaptability to localized hardening is effectively utilized. Other uses include gears, gear blanks, automatic-transmission parts, shifter forks, machine-gun parts, and fractional-horsepower engine crankshafts, *Fig*. 3.

Today, pearlitic malleable applications are rapidly increasing. In its increased use it does not replace standard malleable, since each material fills important but separate requirements.

Production Characteristics

Cast Steel

Castability • Tolerances
Weldability • Machinability

By Charles W. Briggs
Technical and Research Director
Steel Founders' Society of America
Cleveland, Ohio

WHAT steels can be cast? Millions of steel castings are made in this country every year from numerous composition types. In fact, compositions of steel used for castings are almost unlimited; many compositions produced as steel castings are not adaptable to wrought products because they do not lend themselves to hot or cold working.

Steels cast to final shape consist of all grades of carbon steel from carbon contents of 0.05 per cent for electrical applications to rolls having over 1 per cent carbon. All SAE or AISI grades of low-alloy steel can be produced as castings, as well as various types of copper steels containing upward of 2.00 per cent copper.

The 10 to 14 per cent austenitic manganese steels are cast in considerable tonnages each year, as are all grades of heat-resistant and corrosion-resistant stainless steels.

A number of special-composition cast steels of high molybdenum and vanadium contents are produced for castings for high-temperature service.

POPULAR CAST STEELS: Carbon cast steels of 0.20 to 0.40 per cent carbon constitute the largest single grade of steel castings produced. A list of the more popular compositions as produced for steel castings is given in *Table* 1. However, any and all special compositions can be made.

At present, alloy steel casting production is approximately 30 per cent of the total of all types.

TYPICAL PROPERTIES: The properties of the various cast steels given in *Table* 1 and of others produced in the industry are presented in detail in other references[1]. Typical properties of various steels, however, can be obtained by reviewing *Figs*. 1, 2 and 3. Properties shown are available in all directions and are not subject to degree of orientation resulting from direction of working as in wrought products. Hardenability bands for cast

[1]References are tabulated at end of article.

steels are similar to those of wrought steels.

Castability: Rigidity of a section often governs the minimum thickness to which a section can be designed. There are cases, however, when a very thin section will suffice, depending on strength and rigidity calculations.

Fluidity of steel in comparison with other molten metals is known to be lower. For sections to be completely run, a minimum section thickness must be adopted.

Metal cools as it runs in a section through a mold; thus a thin section close to the gate which delivers the molten steel will run, whereas the same thin section at a distance from the gate may not run. Since the design engineer has no knowledge of the location of the gate, a minimum thickness of 1/4-inch must be suggested for design

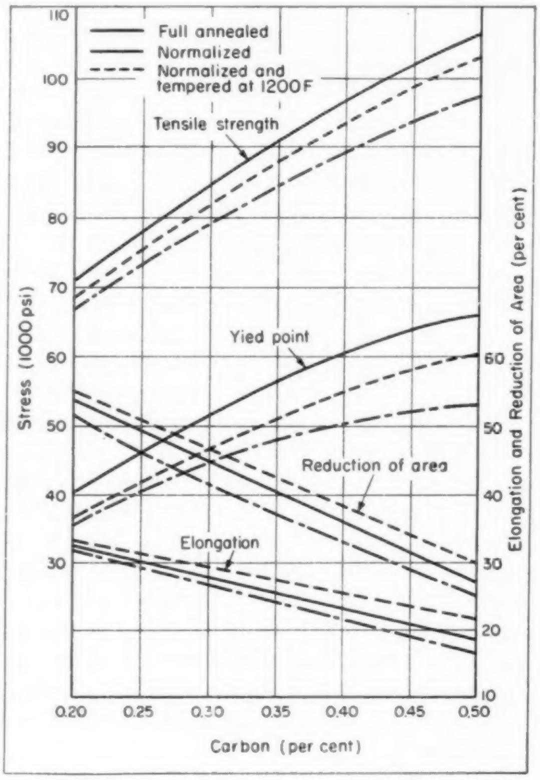


Fig. 1—Left—Comparison of full-annealed, normalized, and normalized and tempered properties of medium-carbon cast steels

Fig. 2—Below—Normal expected range of brinell hardness as a function of tensile strength for low-alloy cast steels, regardless of heat treatment

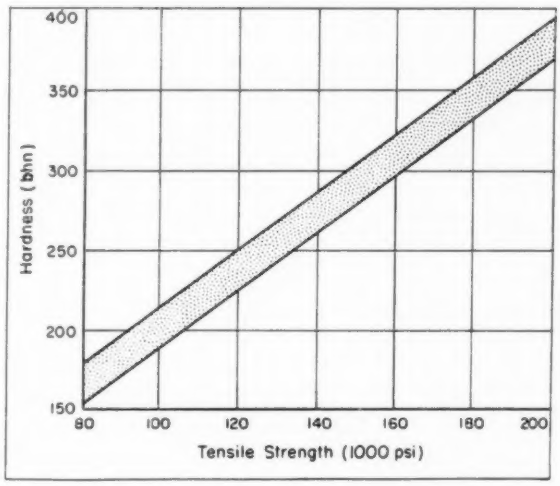


Table 1—Popular Steel Casting Compositions

Type	Similar AISI Type	Alloy* (per cent) C	Mn	Cr	Ni	Mo	Other
Medium carbon	10XX	0.20–.40	0.50–1.00	....	....	....	....
Low carbon	10XX	0.10–.20	0.50–1.00	....	....	....	....
High carbon	10XX	0.40–.80	0.50–1.00	....	....	....	....
Mn	13XX	0.20–0.50	1.25–1.75	....	....	....	....
Mn-Mo	†	0.18–0.50	1.00–1.35	....	....	0.10–0.30	....
Mn-Mo	§	0.18–0.50	1.35–1.75	....	....	0.30–0.35	....
Ni	23XX	0.15–0.50	0.40–0.90	....	2.0–4.0	....	....
Ni-Cr	31XX	0.30–0.50	0.60–1.00	0.45–0.90	1.25–1.75	....	....
Ni-Mo	46XX	0.20–0.45	0.60–0.80	....	1.50–2.00	0.20–0.40	....
Ni-Cr-Mo	86XX	0.20–0.50	0.60–1.00	0.45–0.70	0.45–0.80	0.15–0.30	....
Ni-Cr-Mo	43XX	0.20–0.50	0.60–1.00	0.55–0.80	1.40–2.00	0.20–0.40	....
Mo	40XX	0.07–0.50	0.60–1.00	....	....	0.20–0.50	....
Cr	51XX	0.15–1.00	0.60–1.00	0.70–1.10	....	....	....
Mn-Ni-Cr-Mo	95XX	0.25–0.45	1.25–1.60	0.55–0.75	0.40–1.40	0.30–0.40	....
Cu-Mn-Si	.....	1.50–1.80	0.90–1.25	....	....	....	0.85–1.10 Si, 1.50–1.80 Cu
10-14 Mn	.....	1.00–1.40	10.00–14.00	....	....	....	0.30–1.00 Si
4-6 Cr	501	0.20 max	0.40–0.70	4.00–6.50	....	....	‡
11-14 Cr	410	0.15–0.40	1.00 max	11.5–14.0	1.00 max	0.50 max	....
18-8 Cr-Ni	321	0.08–0.20	1.50 max	18–21	8–11	....	2.00 max Si
25-12 Cr-Ni	309	0.10–0.20	1.50 max	22–26	12–15	....	2.00 max Si
35-15 Ni-Cr	330	0.35–0.75	2.00 max	13–17	33–35	0.50 max	2.50 max Si

*Remainder Fe; plus 0.35-0.80 Si. †8000—old NE steel still popular. †8400—old NE steel still popular. §0.75-1.25 W, or 0.40-0.70 Mo, or 0.75-1.00 Ti.

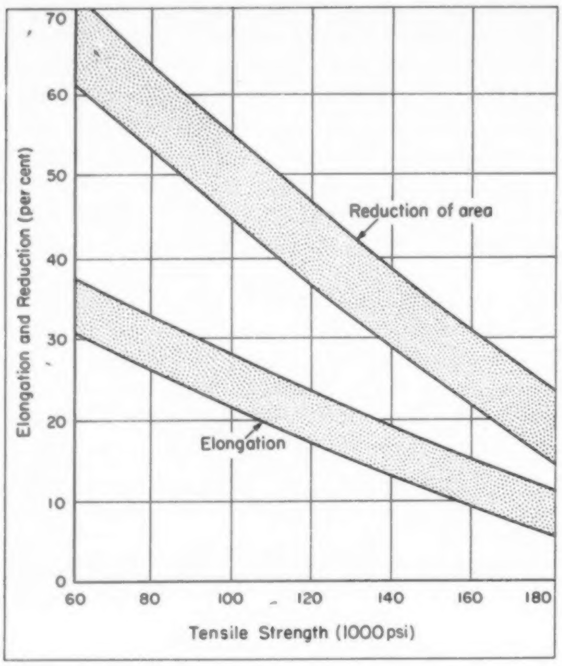


Fig. 3—Normal expected range for ductility as a function of tensile strength for quenched and tempered low-alloy cast steels

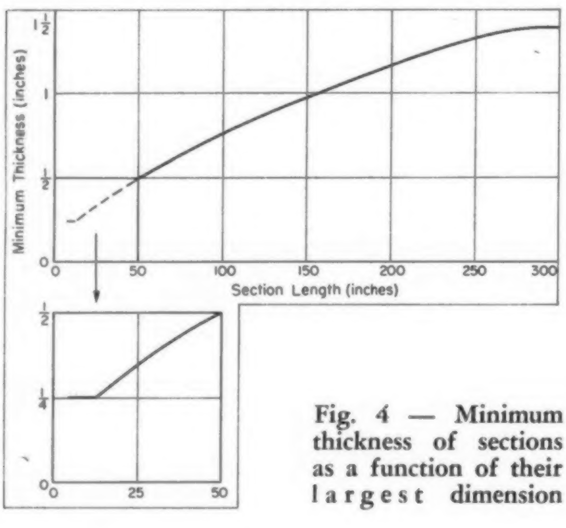


Fig. 4 — Minimum thickness of sections as a function of their largest dimension

use.

Steel flows best for a given thickness in a narrow, rather than in a wide, web. If the ¼-inch thick section is longer than 12 inches, then the minimum thickness should be increased in accordance with the values of *Fig.* 4. Curves of this chart represent the best of design conditions wherein molten steel enters at one position on the casting and must run the lengths prescribed on the chart. Of course, provisions may be made by the foundryman through the application of special techniques to pour even longer members through thinner sections than indicated.

Special casting techniques consist of the centrifugal casting of steel in metal or refractory molds. In such cases steel can be forced through thin sections by centrifugal action.

Also, molds for steel castings can be produced in shell molds, ceramic type molds and heated molds which will permit changes in gating systems and increased runability of steel. However, the application of special techniques is usually responsible for increased cost of production.

All the various composition types lend themselves about equally well to design requirements. The 4 to 6 per cent and the 10 to 14 per cent chromium steels tend to form surface folds during the running of the mold because of the tough chrome oxide films that are formed. However, copper-silicon cast steels will run rather thin long members.

Also, certain of the alloy steels—such as the nickel-chromium steels—of compositions in the 43XX range are more prone to tear at the very high temperatures unless care is taken by the foundrymen.

Shrinkage characteristics of all the steels are very similar; therefore, standard rules apply for their compensation.

Tolerances: Steel castings which incorporate low factors of safety, and are critically designed for maximum strength or weight saving, may have specified restrictions regarding certain—or all—casting sections of the part. This section-thickness tolerance should be ±5 per cent of the casting section for castings having sections up to 2 inches, and ±10 per cent in sections greater than 2 inches, or large heavy castings.

Tolerances for weight limitations are only specified on castings that have been previously cast and a weight established. Estimated weights are often at considerable variance with actual weights. But after the weight has been established on a particular casting, this weight will not vary by more than ±10 per cent.

Dimension tolerances of steel castings used without machining are closely aligned to contraction requirements of the steel casting. Practical values which can act as guides concerning nonmachined steel castings are given in *Table* 2. These values are based on the longest dimension in the casting.

Production to Specific Requirements: Steel castings can be produced to meet specified requirements for mechanical or production properties.

HIGH STRENGTH: Cast steels are produced to tensile strengths of 150,000 to 200,000 psi with

Table 2—Dimensional Tolerances for Steel Castings*

Sand castings	
Smaller than 12 inches	$0.06 + 0.006D$†
Between 12 and 36 inches	$0.06 + 0.006D$
Between 36 and 120 inches	$0.08 + 0.006D$
Shell-molded castings	$0.015 + 0.005D$
Investment castings	0.005 in./in.
Centrifugally cast tubes	$\pm\frac{1}{16}$-in. on OD

D=longest dimension of casting in inches.
*For castings not to be machined. †$\frac{1}{16}$-inch minimum.

ductility of better than 15 per cent reduction of area. Castings are available for dynamic services and consist of low-alloy cast steels with carbon contents below 0.40 per cent, water quenched and tempered.

These steels present no particular production problems: they are weldable, and as long as heat treatment constitutes the final operation there is no difficulty in casting production or securing casting properties. Most of the castings in this classification are relatively lightweight, with sections from 3/8 to 2 inches thick.

TOUGHNESS: Tough cast steels are those that have excellent impact properties, both normal and low-temperature ones. The low-alloy cast steels, containing no free ferrite after quench and tempering, will have Charpy V-notch impact values of greater than 35-foot-pounds at -40 F. These steels have found excellent service as castings for armored vehicles, transportation equipment and dynamic parts subject to shock impact loads.

Production control centers around the selection of alloys to produce through-hardening structures upon liquid quenching. Hardenability testing must be carried on by the foundry to match section size and steel chemistry to service requirements.

HIGH HARDNESS: Cast steel of exceptionally high hardness can be produced. Two classes are available depending upon casting design. Castings of very complicated structures that cannot be liquid quenched because drastic section variations will produce quench cracking are poured from high-carbon steels, either carbon or alloy. Castings that can be successfully quenched without cracking are produced in 0.30 to 0.40 per cent carbon low-alloy cast steels. Hardnesses from 450 to 525 brinell are readily obtainable. Cold working of 12 to 14 per cent manganese steel castings produces hardnesses greater than 500 brinell. This can be done by peening the surface prior to casting installation. However, the usual method is to obtain the work-hardened surface through actual service conditions.

ELECTRICAL (DYNAMO) CHARACTERISTICS: Cast dynamo steels are being used to great advantage by the electrical industry. These steels contain about 0.10 per cent carbon content with other alloys held to a minimum, and the castings are given a full-anneal heat treatment. Main requirement in the production of this steel is to eliminate the possibility of casting porosity. Since the manganese content is usually specified as 0.20 per cent maximum, the steel must be deoxidized with only silicon.

STATIC LOADING: Most steel castings for structural applications, where only static loading exists, are carbon cast steels of 0.25 to 0.40 per cent carbon. These steels are produced to three or four strength levels of minimum tensile strength of from 60,000 to 80,000 psi. Almost all castings to these strength requirements are given a normalize or normalize and temper heat treatment.

A small percentage of alloy steels is employed for structural purposes. These are air-hardening steels however, and they are employed because of increased casting sections and because stress conditions may be other than simple static loading; but the nature of the stress is unknown to the designer.

DYNAMIC LOADING: Steel castings in this classification vary from 70,000 to 200,000 psi tensile strength. Whenever possible, they are purchased to property requirements rather than to chemical analysis specifications. Most of the national specifications, such as ASTM, SAE and AAR, specify the tensile properties and, in some cases, hardness, impact values and hardenability bands. They permit the foundry to select the alloy compositions to meet the specified mechanical properties.

Since most steel castings are produced in the range of 0.25 to 0.35 per cent carbon they can

Table 3—Ferritic Alloy Cast Steels for Extreme-Temperature Service

ASTM Grade		Alloy* (per cent) C	Mn	Ni	Cr	Mo	Va	Si
High Temperature								
C-Mo	WC1	0.25	0.50–0.80	....	....	0.45–0.65	....	0.60 max
Ni-Cr-Mo	WC4	0.20	0.50–0.80	0.70–1.10	0.50–0.80	0.45–0.65	....	0.60 max
Ni-Cr-Mo	WC5	0.20	0.40–0.70	0.60–1.00	0.50–0.90	0.90–1.20	....	0.60 max
Cr-Mo	WC6	0.20	0.50–0.80	....	1.00–1.50	0.45–0.65	....	0.60 max
Cr-Mo	WC9	0.18	0.40–0.70	....	2.00–2.75	0.90–1.20	....	0.60 max
Cr-Mo	C5	0.20	0.40–0.70	....	4.00–6.50	0.45–0.65	....	0.75 max
Cr-Mo	C12	0.20	0.35–0.65	....	8.00–10.00	0.90–1.20	....	1.00 max
Cr-Mo-Va	C23	0.20	0.30–0.80	....	1.00–1.50	0.45–0.65	0.15–0.25	0.60 max
Cr-Mo-Va	C24	0.20	0.30–0.80	....	0.80–1.20	0.90–1.20	0.15–0.25	0.60 max
Low Temperature								
Mn	LCB	0.30	0.70	....	....	....	....	0.60 max
Mn-Mo	LC1	0.25	0.50–0.80	....	....	0.45–0.65	....	0.60 max
Mn-Ni	LC2	0.25	0.50–0.80	2.00–3.00	....	....	....	0.60 max
Mn-Ni	LC3	0.15	0.50–0.80	3.00–4.00	....	....	....	0.60 max

*Remainder Fe.

be successfully water quenched and, therefore, they can develop excellent toughness and shock impact resistance.

HIGH PRESSURES AT EXTREME TEMPERATURES: Steel castings have an extensive field of application in equipment designed for high pressure at various temperatures. Compositions of these steels are devised with the idea of securing good properties at elevated temperatures. They must have excellent resistance to creep, high strength properties at the operating temperature of the equipment, and resistance to the formation of graphite flakes, which may develop in standard compositions upon repeated use of wrought and cast steel at elevated temperatures. At low temperatures a composition must be selected that will not show a brittle fracture. Composition of the cast steels acceptably used for these services are given in *Table* 3. Service applications are from 900 to 1200 F and from 0 to −100 F.

Steel castings for heavy-walled steam-turbine application are produced in several grades of an ASTM specification with tensile strengths from 65,000 to 100,000 psi.

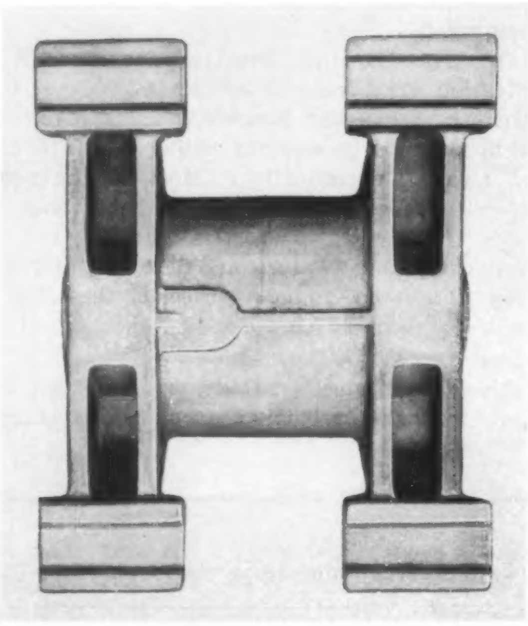
WEAR RESISTANCE: Wear resistance is not an inherent property to be measured in absolute units. It does not exist apart from the conditions of service. Some investigators have found little correlation between wear tests and hardness of the steel, while others show that the greater the hardness number, the less the abrasion. Certain service applications may require high hardness while others require that extreme brittleness, chipping or spalling of surfaces, which may accompany high hardness, are not acceptable.

Steel castings of high wear resistance with excellent shock-resisting properties are available. Cast steels react to wear resistance similarly to wrought steels and give corresponding values depending upon analysis, structure and hardness. For best results, a quenching treatment followed by low-temperature tempering to a mixture of martensite and low-temperature bainite gives the best results. The alloys normally added to cast steel to improve toughness also improve wear resistance, such as molybdenum, chromium, manganese and nickel.

The 12 to 14 per cent manganese cast steels give good wear resistance if the service pressure is great enough to produce a work-hardened surface. Steel castings of austenitic manganese steel give excellent service life in the working of gravels and rock.

There is a present trend to develop low-alloy quenched and tempered steels to 200,000-250,000 psi with better than average impact resistance for wear resistance.

HEAT AND CORROSION RESISTANCE: Cast steels for these services consist of the high-alloy compositions. Heat-resistant alloys are used under conditions where metal temperatures exceed 1200 F, and the corrosion-resistant alloys are for services in corrosive conditions up to temperatures of 1200 F. These steels usually contain more than 12 per cent alloy. All the grades produced in



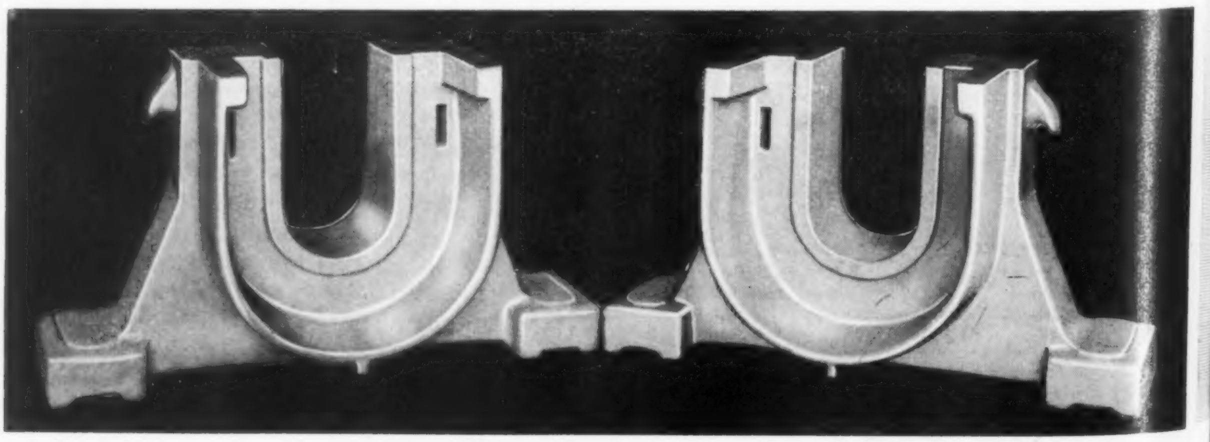


Fig. 5 — Rolling-mill pinion housing weighing 6170 pounds. The casting is split in two parts. Only half a pattern is required, without a main body core. Pattern cost alone was approximately 30 per cent less than with a full pattern and conventional core. The casting was made up in two halves welded together. The cast-weld construction resulted in cost savings of 15 per cent

wrought steel are produced as castings, plus several others that normally may be made in only small quantities adaptable to the short orders of special application.

Workability Characteristics: Two further characteristics of cast steels—weldability and machinability—are usually of interest.

WELDABILITY: All steel can be welded. Most cast steel is readily welded; 95 per cent of the steel castings produced contain less than 0.40 per cent carbon. Steel castings can be welded as readily as wrought steel of similar composition, and the extensive information gathered on the welding of wrought steels can be directly applied to the welding of steel castings. But complete information on the welding of steel castings is also available[2].

With relatively few exceptions, all castings welded are subsequently stress relieved or given a full heat treatment. This eliminates excessive hardness next to the weld and severe weld stresses.

CAST-WELD CONSTRUCTION: Castings should be redesigned for cast-weld construction if a casting is so intricate that producing a one-piece casting is costly, time consuming, and will not produce a quality job.

Extensive and intricate core work, molding and handling of large molds, and difficult cleaning requirements all add to the production costs. In certain cases the complicated casting can be split into parts so that there may be few cores, easy to mold and clean. Also, complicated castings are responsible for complicated problems in solidification for soundness and freedom from high stresses which frequently produce tears. The quality of the casting usually can be improved by cast-weld construction.

Examples of what can be done by the cast-weld method of design are shown in *Figs.* 5 and 6.

COMPOSITE FABRICATION: Structures made up of steel castings, rolled steel plate, forgings, stampings and tubing welded together are considered as a composite fabrication. Weldments should be redesigned for composite fabrication when:

1. A particular part of a weldment is intricate and does not lend itself to simplification by the use of standard shapes and forms.
2. Dimensions of a certain section of a structure are compact to the extent that the welding operation cannot be performed satisfactorily.
3. A weldment requires a number of similar units to complete.

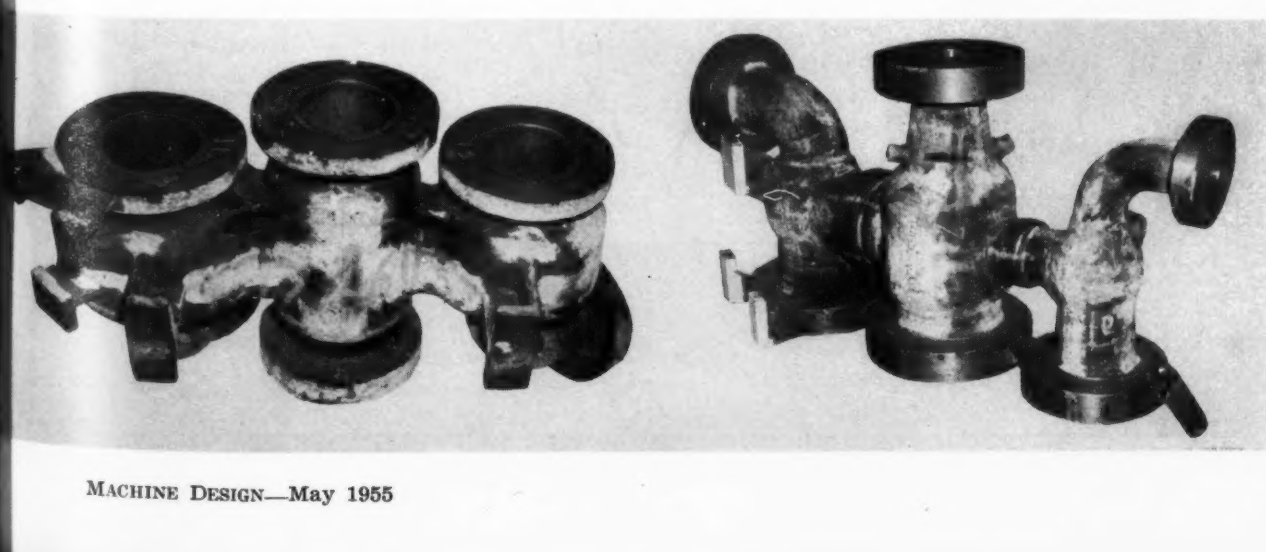
There are many examples of composite fabrication including steel casting. One example of design for composite fabrication is illustrated in *Fig.* 7.

MACHINABILITY: Steel castings, in many cases, are delivered to the customer in the normalized condition. This is not necessarily the heat treatment which produces optimum machining properties. However, in many cases the production requirements may be large enough, and tool and time savings great enough, to offset additional heat-treating costs to develop optimum microstructure conditions for maximum machinability.

In commercial machining the objectives vary widely, and machinability may be evaluated in terms of tool performance as represented by tool life per grind under given conditions; the speed at which the material can be cut, under given conditions, while maintaining a given tool life; and the force required for cutting. Values of machinability are comparative and represent the behavior of the material under given conditions.

Microstructure has a definite effect on the machinability of cast steels.[3] In some cases machining characteristics can be improved as much as

Fig. 6—Single piece steam strainer and valve casting. Large excavations at junctions of the valve bodies shows the location of tears (which were removed). Shrinkage was also found under cast-on brackets. The three bodies were then made as separate castings, and welded together. No difficulty was encountered from casting defects, improved casting quality resulted, as well as lower costs in producing the structure

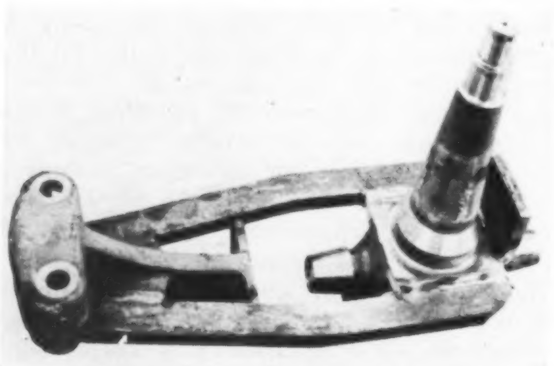


100 to 200 per cent through heat treatment which alters the microstructure. While machinability can be increased by a structure change, the mechanical properties required by the final product must not be overlooked.

Hardness generally has been the criterion for predicting tool life, but hardness alone cannot be used for predicting tool life in the cutting of cast steels.

In the selection of a cast steel for machining purposes, plain carbon steels possess better machining properties than the alloy steels. Machinability of a plain carbon cast steel (1040), when machined with carbides, varies as the ratio of ferrite to pearlite in its microstructure, 60-40 ratio machining the best.

Fig. 7—Hitch assembly for a high-speed earthmover. Pivot spindle is an alloy-steel casting with a 120,000-psi tensile rating, and the steering tail is a carbon-steel casting (75,000 psi). In assembly of the castings to connecting rolled mild-steel bars, a special welding technique of a single pass of stainless steel was laid on the castings before a submerged arc was applied



It has been said that the casting skin wears tools rapidly and for this reason cast steels are considered by many as difficult to machine. This is not the case if a deep cut is taken and, at the same time, only one-half the cutting speed employed on the base metal is used.

The machinability index for high-speed steel tools is not well known. Tests conducted with a standard wrought steel of the free-machining type (B1112), machined at 180 sfpm and giving a tool life of 2 to 3 hours, have been selected as the reference base. Results are shown in *Table* 4.

Wrought and cast steels of similar microstructure have been compared and the results indicate that when high-speed tools are used and a practical speed maintained, the steels have comparable machining characteristics. Also, machining results, using carbide tools, are roughly comparable except at low speeds of 300 fpm. Better performance of wrought steels at this level indicates they are less abrasive. At higher speeds, however, abrasiveness is not as important in tool breakdown as the temperature developed at the tool interface. Normal cutting speeds on carbide tools, however, are above 500 fpm.

REFERENCES

1. *Steel Castings Handbook*, Steel Founders' Society, Cleveland, 1950.
2. *Recommended Practice for the Welding of Steel Castings*, Steel Founders' Society, Cleveland.
3. N. Zlatin, J. Kahles and C. W. Briggs—"The Machinability of Cast Steels," *Tool Engineer*, Feb., 1953; *Iron Age*, Jan. 22, 1953; *American Machinist*, Feb. 2, 16 and Mar. 2, 1953.

Table 4—Machinability of Steel Castings

Type	Nearest AISI No.	Heat Treatment*	Hardness (bhn)	Speed Index No.† High-Speed Steel	Speed Index No.† Carbide	Microstructure§ (figures are %)
Carbon	1020	A	122	160	400	80B, 20P
Carbon	1020	N	134	135	230	85B+W, 15P
Carbon	1040	N, N	185	130	400	60B, 40P
Carbon	1040	N, A	175	135	380	50B, 50P
Carbon	1040	N	190	120	325	35NF, 65P
Carbon	1040	N, Q	225	80	310	30W, 70P
Med. Mn	1330	N	187	75	140	40B+W, 60P
Med. Mn	1330	N, T	160	120	230	50D, 50P
Mn-Mo		N, T (1200 F)	200	90	200	70W+B, 30P
Mn-Mo		N, T (1275 F)	180	110	240	80W+B, 20P
Cr-Mo	4130	A	175	95	260	40B, 60P
Cr-Mo	4130	N, Sph.	175	90	200	40B, 60S
Ni-Cr-Mo	4340	N, A	200	60	210	40B, 60P
Ni-Cr-Mo	4340	N, Sph.	210	95	290	50B, 50S
Ni-Cr-Mo	4340	Q, T	300	45	200	T
Ni-Cr-Mo	4340	Q, T	400	35	180	T
Ni-Cr-Mo	8630	N	240	75	180	80W, 20P
Ni-Cr-Mo	8630	A	175	120	290	50D, 50P

*A=Annealed; N=Normalized; N, N=Double normalized; N, Q=Normalized and quenched; N, T=Normalized and tempered; N, Sph.=Normalized and spheroidized; Q, T=Quenched and tempered; N, A=Normalized and annealed.

†Actual cutting speed giving a tool life of 1 hr in turning. High-speed steel tool used was standard 18-4-1 grade; carbide was general-purpose steel cutting grade. Tool life was based on measured wear on flank or clearance surface of tool. Wear criterion for high-speed steel was 0.060-in. or complete nose breakdown, whichever occurred first; for carbide was 0.015-in. uniform flank wear or 0.040-in. localized failure.

§B=Blocky ferrite; D=Dendritic blocky ferrite; NF=Network ferrite; P=Pearlite; S=Spheroidized carbide; T=Tempered martensite; W=Widmanstatten ferrite.

Production Characteristics

Cast Stainless Steel

Machinability • Welding procedures
Heat treatment

By E. A. Schoefer
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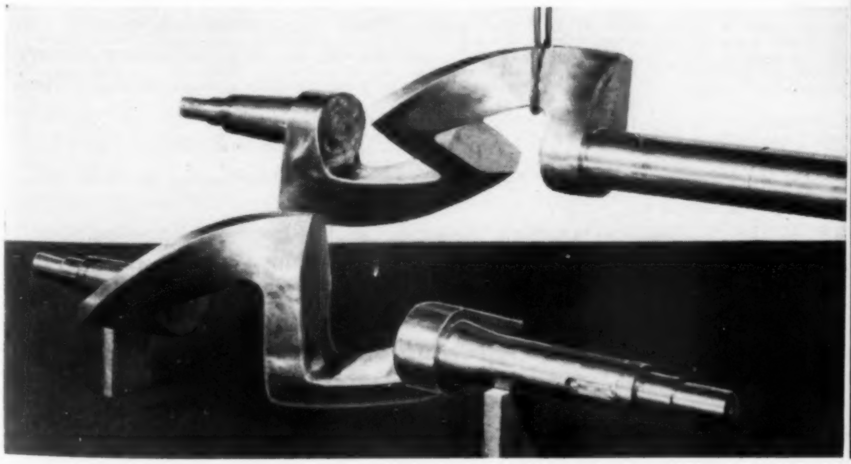
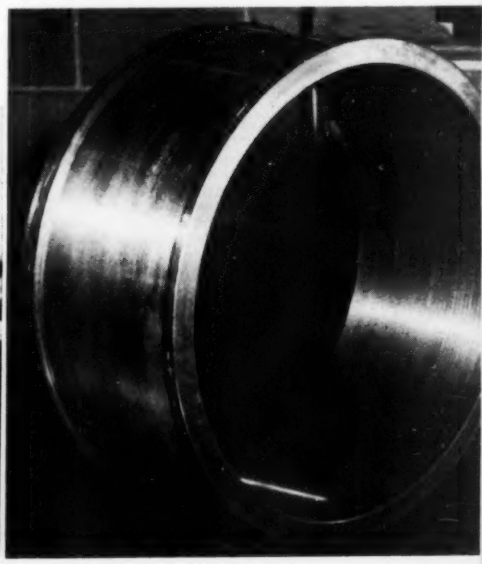
ALL of the stainless alloys produced in wrought form are also available as castings. In addition, many special compositions for handling specific corrodents or for high-temperature structural parts can be obtained in the cast form.

General corrosion and heat-resistance characteristics of the cast materials are similar to those of the wrought grades. But because cast alloy chemical composition ranges are not exactly the same as the wrought (AISI) composition ranges, cast alloy designations (ACI) should be used for proper identification of castings, *Table* 1.

Wrought alloys normally contain less than 0.50 per cent silicon, whereas in cast alloys the silicon content may be as high as 1.50 per cent or more. High silicon content is important in promoting castability of the alloys but, in conjunction with high chromium, tends to make castings of the austenitic grades partially ferritic and hence mag-



Blades for this mixer-blade assembly are cast of corrosion resistant CF-8 stainless alloy. Forged 18-8 stainless end-shafts are shrunk on and welded in position



Centrifugally cast CK-20 stainless alloy provides necessary heat resistance for jet-engine rings. Each ring weighs 90 pounds

Table 1—Standard ACI Cast Stainless Alloys

Designation (Alloy Casting Institute)*	Corresponding Wrought Alloy Type†	Nominal Composition (%, bal Fe): C	Cr	Ni	Other§
Corrosion-Resistant Grades					
CA-15	410	0.15 max	11.5-14	1 max	....
CA-40	420	0.20-0.40	11.5-14	1 max	....
CB-30	431	0.30 max	18-22	2 max	....
CC-50	446	0.50 max	26-30	4 max	....
CE-30	...	0.30 max	26-30	8-11	....
CF-8	304	0.08 max	18-21	8-11	....
CF-20	302	0.20 max	18-21	8-11	....
CF-8M	316	0.08 max	18-21	9-12	2.0-3.0 Mo
CF-12M	316	0.12 max	18-21	9-12	2.0-3.0 Mo
CF-8C	347	0.08 max	18-21	9-12	Cb or Cb-Ta‡
CF-16F	303	0.16 max	18-21	9-12	1.5 max Mo, 0.20-0.35 Se
CH-20	309	0.20 max	22-26	12–15	....
CK-20	310	0.20 max	23-27	19–22	....
CN-7M	...	0.07 max	18-22	21–31	Mo-Cu**
Heat-Resistant Grades					
HA	...	0.20 max	8-10	...	0.90-1.20 Mo
HC	446	0.50 max	26-30	4 max	....
HD	327	0.50 max	26-30	4–7	....
HE	...	0.20-0.50	26-30	8–11	....
HF	302B	0.20-0.40	19-23	9–12	....
HH	309	0.20-0.50	24-28	11–14	....
HI	...	0.20-0.50	26-30	14-18	....
HK	310	0.20-0.60	24-28	18-22	....
HL	...	0.20-0.60	28-32	18-22	....
HN	...	0.20-0.50	19-23	23–27	....
HT	330	0.35-0.75	13-17	33–37	....
HU	...	0.35-0.75	17-21	37–41	....
HW	...	0.35-0.75	10-14	58–62	....
HX	...	0.35-0.75	15-19	64-68	....

*Most standard grades listed are covered for general application by ASTM specifications A296-49T and A297-49T. ASTM specifications A217-49T, A351-52T, A362-52T, B190-50 and B207-50 also apply to some grades.

†Listed only for convenience in determining corresponding wrought and cast grades. Because cast alloy chemical composition ranges are *not the same* as wrought composition ranges, cast alloy designations should be used for proper identification.

‡Cb—8×C min, 1.0 max; or Cb-Ta—10×C min, 1.35 max.

**Several proprietary alloy compositions fall within the stated chromium and nickel ranges, and contain varying amounts of silicon, molybdenum and copper. These are available from licensed producers only.

§Silicon: 1.00 max—CB-30, CC-50, HA; 1.50 max—CA-15, CA-40, CF-8M, CF-12M; 2.50 max—HT, HU, HW, HX; 3.00 max—HK, HL; all other grades, 2.00 max. Manganese: 1.00 max—CA-15, CA-40, CB-30, CC-50, HC; 1.50 max—all other C grades and HC; 2.00 max—all other H grades; 0.35-0.65—HA.

Table 2a—Machining Speeds and Feeds: Corrosion-Resistant Grades

Alloy Type	Rough Turning: Speed* (sfpm)	Rough Turning: Feed (ipr)	Drilling Speed (sfpm)	Tapping Speed (sfpm)
CA-15	40-50	0.010-0.030	35-70	10-25
CA-40	25-35	0.030-0.040	30-60	10-20
CB-30	40-50	0.020-0.030	30-60	10-25
CC-50	40-50	0.025-0.035	40-60	10-25
CE-30	30-40	0.020-0.025	30-60	10-25
CF-8	25-35	0.020-0.025	20-40	10-20
CF-20	25-35	0.020-0.025	20-40	10-20
CF-8C	30-40	0.020-0.025	30-60	10-25
CF-8M	25-35	0.020-0.025	20-50	10-20
CF-12M	25-35	0.020-0.025	20-50	10-20
CF-16F	45-55	0.020-0.025	30-80	15-30
CH-20	25-35	0.020-0.025	20-50	10-20
CK-20	25-35	0.020-0.025	20-40	10-20
CN-7M	45-55	0.020-0.025	30-60	10-25

*For high-speed tools; about twice these speeds for carbide tools.

Table 2b—Machining Speeds and Feeds: Heat-Resistant Grades

Alloy Type	Rough Turning: Speed* (sfpm)	Rough Turning: Feed (ipr)	Drilling Speed (sfpm)	Tapping Speed (sfpm)
HC	40-50	0.025-0.035	40-60	10-25
HD	40-50	0.025-0.035	40-60	10-25
HE	30-40	0.020-0.025	30-60	10-25
HF	25-35	0.020-0.025	20-40	10-20
HH	25-35	0.015-0.020	20-40	10-20
HI	25-35	0.015-0.020	20-40	10-20
HK	25-35	0.020-0.025	20-40	10-20
HL	30-40	0.020-0.025	30-60	10-25
HN	35-45	0.020-0.025	40-60	5-15
HT	40-45	0.025-0.035	40-60	5-15
HU	40-45	0.025-0.035	40-60	5-15
HW	40-45	0.025-0.035	40-60	5-15
HX	40-45	0.025-0.035	40-60	5-15

*For high-speed tools; about twice these speeds for carbide tools.

Table 3a—Welding Procedures: Corrosion-Resistant Grades

Alloy Type	Heat Treatment (deg F): Preweld	Heat Treatment (deg F): Postweld*	Electrode Type No.
CA-15	400-600	Cool to 300 min, AC from 1125-1450	410
CA-40	400-600	Cool to 300 min, AC from 1125-1450	420
CB-30	600-800	Cool to 150 max, heat to 1450, AC	431
CC-50	350-400	Heat to 1650 then rapidly air cool	446
CE-30	None	none†	309
CF-8	None	WQ from 1950-2050	308
CF-20	None	WQ from 2000-2100	308
CF-8C	None	none‡	347
CF-8M	None	WQ from 1950-2100	316
CF-12M	None	WQ from 1950-2100	316
CF-16F	None	WQ from 2000-2100	308
CH-20	None	WQ from 2000-2100	309
CK-20	None	WQ from 2000-2150	310
CN-7M	400	Cool very slowly, heat to 2000, WQ	§

*Time at postweld temperature should be sufficiently long to insure uniform heating throughout the areas and sections involved. Quenching of chromium-nickel grades should be drastic enough to insure a rapid rate of cooling from 1600 to 800 F. Air or oil quenching may be adequate with light sections and low-carbon alloys. AC=air cool; WQ=water quench.

†Postweld heat treatment usually is not necessary; however, corrosion resistance and ductility can be improved somewhat by quenching from about 2000 F.

‡Postweld heat treatment (WQ from 1950-2050 F) advisable if stress-corrosion is a factor.

§Rod of composition equivalent to cast alloy is available and should be used.

Table 3b—Welding Procedures: Heat-Resistant Grades

Alloy Type	Heat Treatment: Preweld (F)	Heat Treatment: Postweld	Welding Method: Gas: Bare Rod Type	Welding Method: Gas: Acetylene Richness	Welding Method: Arc: Lime-Coated Electrode Type
HA	450–550	*	†	†	410
HC	600–1000	§	†	†	446
HD	350–400‡	**	†	†	446
HE	None	None	†	†	312
HF	None	None	†	†	308
HH	None	None	309	Slight	309
HI	None	None	309	Slight	309
HK	None	None	310	Medium	310
HL	None	None	310	Medium	310
HN	None	None	330	Very	330
HT	None	None	330	Very	330
HU	None	None	330	Very	330
HW	None	None	Inconel††	Very	Inconel
HX	None	None	Inconel††	Very	Inconel

*1200–1300 F; hold until uniform; air cool. †Arc welding preferred. §1550 F; hold until uniform; rapid air cool. ‡Usually not required. **Usually not required except for relief of welding stresses. ††Use of stainless flux recommended.

netic. Experience shows that such partially ferritic alloys have corrosion resistance essentially equivalent to the fully austenitic alloys.

The cast stainless alloys may be employed for complex designs, and all of the grades can be welded and machined. However, there are some differences in the fabricating qualities of the different grades, as indicated in *Tables* 2 and 3. With respect to intricacy of design, the straight-chromium grades are somewhat more difficult to handle than the chromium-nickel types.

Comparisons presented in the tables constitute

a general guide only. Several considerations, however, should not be overlooked. First, dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to $\frac{1}{16}$-inch per foot. Second, the type of pattern equipment required will often differ, depending on the foundry producing the casting.

Surface-finishing operations such as grinding, buffing and polishing, can be performed satisfactorily on all the cast alloys.

Production Characteristics

Brass, Bronze and Copper

Stamping • Drawing • Shearing • Forming Bending • Cold and hot forging • Heading Upsetting • Machinability

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COPPER and copper-base alloys are a large and diverse family of metals, with widely different characteristics. Often appearance is the characteristic desired in design; colors ranging from the red of copper through the yellow of brass to the silvery-white of nickel silver are available. Or corrosion resistance, high electrical and thermal conductivity or low magnetic permeability may be determining factors in use of a copper-base alloy.

But production characteristics—emphasized in this discussion—are also quite favorable. Copper-base alloys generally are easily cold and hot worked; machinability is an outstanding characteristic for many of the brasses; brazing, soldering and welding are efficient; and finishing and plating characteristics are superior.

The copper and copper-base alloys will be covered in two sections: (1) the engineering coppers, and (2) copper alloys.

Engineering Coppers: The Copper & Brass Research Association defines "copper" as the element copper, commercially pure, or alloyed with not more than 1 per cent of other elements. Although many combinations of metals fall into this category, normally about 20 distinctive types are

Table 1—Fabrication Properties: Copper

Copper Designation	Cold Working	Hot Working	Hot Working Range (deg F)	Commercial Annealing Range (deg F)	Machinability Rating*
Electrolytic tough pitch	Excellent	Excellent	1400-1600	700-1200	20
Phosphorized deoxidized	Excellent	Excellent	1400-1600	700-1200	20
Oxygen free	Excellent	Excellent	1400-1600	700-1200	20
Tellurium phosphorized	Good	Excellent	1400-1600	700-1200	90

* Free-cutting brass = 100.

Table 2—Joining Properties: Copper

Copper Designation	Soft Soldering	Brazing	Welding: Oxy-acetylene	Welding: Carbon Arc	Welding: Metal Arc	Welding: Inert Gas Arc
Electrolytic tough pitch	Excellent	Good	Poor	Fair	Fair	Fair
Phosphorized deoxidized	Excellent	Excellent	Fair	Good	Good	Excellent
Oxygen-free	Excellent	Excellent	Fair	Good	Good	Excellent
Tellurium phosphorized	Good	Fair	Poor	Poor	Poor	Good

commercially available. Coppers are subdivided into three major groups:

1. Those containing controlled amounts of oxygen in the form of cuprous oxide. Those having from 0.02-0.05 per cent oxygen as cuprous oxide are called electrolytic tough-pitch coppers.
2. Those containing no cuprous oxide. Among these, phosphorized-deoxidized coppers and oxygen-free coppers are widely used.
3. Those which have been modified by adding small quantities of other elements to achieve better machinability or for other production needs.

Oxygen-free copper, *Table* 1, is slightly more ductile than tough pitch and can be more severely cold worked. In joining by brazing or welding, *Table* 2, cuprous oxide in tough-pitch copper introduces certain problems because of the possibility of embrittlement if the copper is heated in a reducing atmosphere.

The three basic coppers (electrolytic tough-pitch, phosphorized-deoxidized, and oxygen-free) have relatively poor machining characteristics as compared with free-cutting brass rod. However, for screw machine and similar cutting applications, all three can substantially be improved by adding certain elements to increase machinability.

Originally, free-machining copper contained about 1 per cent lead. But in recent years this composition has been superseded by tellurium and selenium-bearing copper. These elements supply free-machining qualities while retaining favorable fabricating qualities.

Table 3—Minimum Bend Radii: Copper Strip*

Condition	Across Grain (in.)	Angle § (in.)	With Grain (in.)
Cold-rolled 2 B & S No. hard	1/32	1/32	3/64
Cold-rolled 6 B & S No. hard	1/64	1/32	1/32

* 0.020-inch thick. § 45 degrees to rolling direction.

Table 4a—Fabrication Properties: Brasses

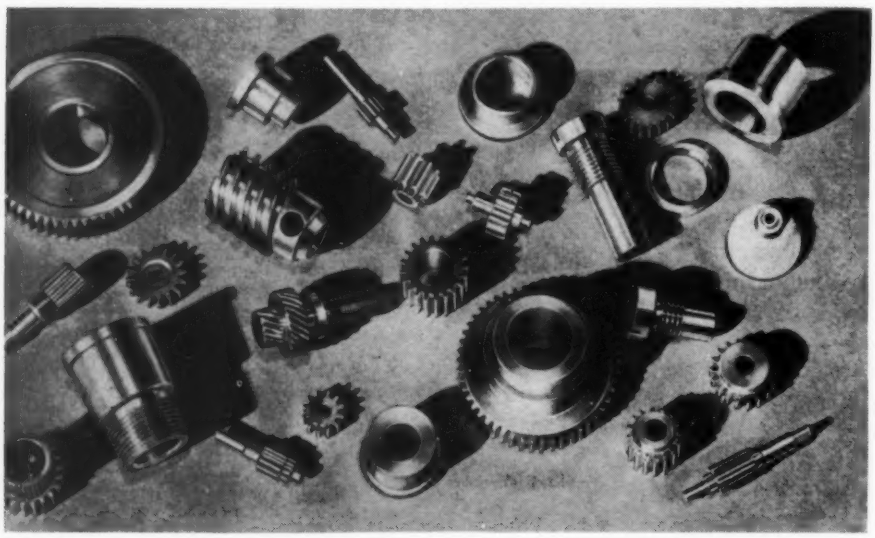
Alloy	Cold Work	Hot Work	Machinability
Brasses			
Gilding metal 95%	Excellent	Good	20
Commercial bronze 90%	Excellent	Good	20
Red brass 85%	Excellent	Good	30
Low brass 80%	Excellent	Fair	30
Cartridge brass 70%	Excellent	Fair	30
Yellow brass	Excellent	Poor	30
Muntz metal	Fair	Excellent	40
Leaded Brasses			
Leaded commercial bronze	Good	Poor	80
Low-leaded brass	Good	Poor	60
Medium-leaded brass	Good	Poor	70
High-leaded brass	Fair	Poor	90
Extra high-leaded brass	Poor	Fair	100
Free-cutting brass	Poor	Fair	100
Leaded Muntz metal	Fair	Excellent	60
Free-cutting Muntz metal	Fair	Excellent	70
Forging brass	Poor	Excellent	80
Architectural bronze	Poor	Excellent	90
Tin and Aluminum Brasses			
Inhibited Admiralty	Excellent	Fair	30
Naval brass	Fair	Excellent	30
Leaded Naval brass	Poor	Good	70
Manganese bronze (A)	Poor	Excellent	30
Aluminum brass	Excellent	Fair	30

Table 4b—Fabrication Properties: Phosphor Bronzes

Alloy	Cold Work	Hot Work	Machinability
Phosphor bronze 5%	Excellent	Poor	20
Phosphor bronze 8%	Good	Poor	20
Phosphor bronze 10%	Good	Poor	20
Phosphor bronze 1.25%	Excellent	Good	20

Table 4c—Fabrication Properties: Nickel Silvers

Alloy	Cold Work	Hot Work	Machinability
Nickel silver 65-18	Excellent	Poor	20
Nickel silver 55-18	Good	Poor	30
Nickel silver 65-15	Excellent	Poor	20
Nickel silver 65-12	Excellent	Poor	20
Nickel silver 65-10	Excellent	Poor	20



Screw-machine parts and cut gears are often made from leaded copper-base alloys for easy machinability. Parts include bearings, bushings, valve and pump parts, gears and pinions

Coppers can be hardened by cold working. When "full hard" the metal has about twice the tensile strength as in the original cast condition. There is one exception: chromium copper, a precipitation-hardening metal, can be heat treated to high strength and hardness (tensile strength as high as 72,000 psi; hardness, 77 Rockwell B).

In general, coppers are extremely ductile and will not work-harden as rapidly as brass and bronze. Consequently the metal can be cold worked severely, with reductions permissible up to 90 per cent. While all grades can be said to have roughly the same cold-working characteristics, phosphorized-deoxidized and oxygen-free varieties can withstand slightly more bending and forming than tough pitch.

In press working, where cupping and drawing are involved, copper is somewhat less ductile than 70-30 brass. Nevertheless the metal has good formability and is readily stamped, coined and embossed. Copper is excellent for spinning. For best results an annealed sheet with a controlled grain size is recommended.

When bending and forming cold-rolled strip copper, direction of the bend should be watched. Cold-rolled tempers are bent more readily across the rolling direction than parallel to it. This characteristic is important when extremely sharp bends must be made, *Table* 3. Naturally, a soft, thin material withstands more drastic bends than a hard, thick sheet.

All grades of copper, except for leaded varieties, exhibit good hot-working characteristics. In heavy-wall pipe, pressure-vessel heads and similar large-section work, hot bending and forming achieve good results. Electrolytic tough-pitch and phosphorized-deoxidized coppers are generally used; they are hot forged and pressed at temperatures from 1400 to 1600 F.

MACHINING: If the machinability of free-cutting brass is arbitrarily called 100, the Copper & Brass Research Association rates commercially pure copper as having a machinability of 20, *Table* 1. Some users consider tough-pitch copper slightly more machinable than oxygen-free or phosphorized-deoxidized and rate it at 25.

Standard tooling is generally satisfactory for copper, although tools with a large rake angle are required for turning. High-speed cutting tools and milling gears can safely be used. Cross-tool spiral or helical gears will produce fine surfaces on coppers if appropriate rake and clearance angles are used. Similarly, standard twist drills with a full rake angle work well. For long runs in production, drills with a greater number of twists per inch are recommended because the increased rake angle assists in chip removal.

Free-cutting coppers—those containing lead, selenium, and tellurium—have a machinability rating of 80-90. Used mainly in screw-machine operations, these alloys can use the same tooling as free cutting brass.

JOINING: Coppers can be joined by soldering, brazing or welding, *Table* 2. The metal's high thermal conductivity and high electrical conductivity require that certain precautions be taken—depending on the joining method used. No dif-

High mechanical properties combined with good formability are characteristic of phosphor bronze. Often used for springs, clips and electrical parts made from strip or wire, this alloy has high fatigue, tensile and yield strengths combined with good ductility and resilience

Table 5a—Joining Properties: Brasses

Alloy	Soft Soldering	Silver Alloy Brazing	Welding: Oxy-acetylene	Welding: Carbon Arc	Welding: Resistance
Brasses					
Gilding Metal 95%	Excellent	Excellent	Fair	Good	Poor
Commercial bronze 90%	Excellent	Excellent	Good	Good	Poor
Red brass 85%	Excellent	Excellent	Good	Good	Poor
Low brass 80%	Excellent	Good	Good	Fair	Poor
Cartridge brass 70%	Excellent	Good	Good	Fair	Fair
Yellow brass	Excellent	Good	Good	Fair	Fair
Muntz metal	Excellent	Good	Good	Fair	Fair
Leaded Brasses					
Leaded commercial bronze	Excellent	Excellent	Fair	Fair	Poor
Low-leaded brass	Excellent	Good	Fair	Fair	Fair
Medium-leaded brass	Excellent	Good	Fair	Fair	Poor
High-leaded brass	Excellent	Good	Fair	Fair	Poor
Extra high-leaded brass	Excellent	Good	Fair	Poor	Poor
Free-cutting brass	Excellent	Good	Fair	Poor	Poor
Leaded Muntz metal	Excellent	Good	Fair	Poor	Poor
Free-cutting Muntz metal	Excellent	Good	Fair	Poor	Poor
Forging brass	Excellent	Good	Fair	Poor	Poor
Architectural bronze	Excellent	Good	Fair	Poor	Poor
Tin and Aluminum Brasses					
Inhibited admiralty	Excellent	Good	Good	Fair	Fair
Naval brass	Excellent	Good	Good	Fair	Fair
Leaded naval brass	Excellent	Good	Fair	Poor	Poor
Manganese bronze (A)	Excellent	Good	Good	Fair	Good
Aluminum brass	Good	Good	Good	Good	Good

Table 5b—Joining Properties: Phosphor Bronzes

Alloy	Soft Soldering	Silver Alloy Brazing	Welding: Oxy-acetylene	Welding: Carbon Arc	Welding: Resistance
Phosphor bronze 5%	Excellent	Good	Good	Good	Good
Phosphor bronze 8%	Excellent	Good	Good	Good	Excellent
Phosphor bronze 10%	Excellent	Good	Good	Good	Excellent
Phosphor bronze 1.25%	Excellent	Excellent	Good	Good	Fair

Table 5c—Joining Properties: Nickel Silvers

Alloy	Soft Soldering	Silver Alloy Brazing	Welding: Oxy-acetylene	Welding: Carbon Arc	Welding: Resistance
Nickel silver 65-18	Excellent	Excellent	Good	Fair	Excellent
Nickel silver 55-18	Excellent	Excellent	Good	Poor	Excellent
Nickel silver 65-15	Excellent	Excellent	Good	Fair	Excellent
Nickel silver 65-12	Excellent	Excellent	Good	Fair	Excellent
Nickel silver 65-10	Excellent	Excellent	Good	Fair	Excellent

Table 6—Hot Forging and Pressing Alloys

Alloy	Composition	Relative Forgeability
Forging brass	60 Cu, 38 Zn, 2 Pb	100
Muntz metal	60 Cu, 40 Zn	90
Naval brass	60 Cu, 39.25 Zn, 0.75 Sn	90
Leaded naval brass	60 Cu, 37.5 Zn, 0.75 Sn, 1.75 Pb	90
Manganese bronze (A)	58.5 Cu, 39.2 Zn, 1 Sn, 1 Fe, 0.3 Mn	80
Nickel silver 45-10	45 Cu, 45 Zn, 10 Ni	85

ficulties are generally encountered in brazing and soft soldering, except for having the metal surfaces clean and free from greases. Any joining method which quickly raises the material to joining temperature can be used. One exception: leaded copper can not be satisfactorily welded by most usual methods.

Applications: In most applications copper is used for high electrical conductivity, high thermal conductivity, ease of working, strength, and ease of joining.

Electrolytic tough pitch is the most widely used of all coppers. Its uses range from motor transformers and wiring of all types, through kettles and processing vessels to casting, printing rolls and expansion joints. This grade is also widely used in automobiles, particularly for radiators.

Oxygen-free copper is usually selected for applications when tough pitch is not suitable—service at extremely high temperatures and in the presence of reducing gases. Because oxygen-free copper can be joined by hydrogen brazing, a special grade is used for electronic applications.

Phosphorized-deoxidized copper, which can be more severely worked than tough pitch, and more readily welded, is used mainly for fabricated equipment; refrigerators, heat exchangers, welded vessels, and tubular products.

Tellurium copper is used for screw-machine products, welding-torch tips and in electrical applications such as switch parts, contact points, relays, etc.

Chromium copper is used for some welding electrodes and also in electrical equipment where a combination of high strength, hardness and good electrical conductivity are needed.

Copper Alloys: In considering the copper alloys, general fabrication characteristics will first be considered, with detailed discussion of each alloy following. *Tables* 4-6 summarize pertinent characteristics.

Relative Machinability: For convenience, copper alloys are grouped in three categories according to relative machinability. The first group with a machinability of 70 to 100 (with free-cutting brass equalling 100) are the "free-cutting alloys." The second group with a rating of 30 to 60 are called "readily machinable." The last group consists of those alloys having a rating of 20.

These ratings should be considered a general guide since they are based on several factors; speed of machining, tool wear, finish, accuracy and power required. Alloys which produce long, tough, stringy chips are placed arbitrarily in the 20 machinability group.

Drawing Operations: In producing cups by drawing, diameter reductions between 40 and 46 per cent are considered reasonable. Greater or less reductions can be made depending on alloy ductility and thickness, and tool design. Experimental cups have been made with diameter reductions up to 60 per cent. However, with these large reductions it is difficult to regulate blank-holding procedure.

Cold Heading: Plastic deforming of copper-base alloys without the use of heat is widely prac-

ticed. In general, choice of metal, machine and tooling are all important to successful cold heading. For example, using the same diameter wire of equal length, it will take more power to upset this material into a thin large diameter than into a thick smaller diameter.

If an alloy has high tensile strength, more power will be required than for more ductile alloys. If a part has a very long shank, a larger machine will be needed to accommodate the feed and the larger die.

JOINING: The method selected for joining copper-base alloys usually depends on strength needed in the joint. Soft solder, of course, is weakest, brazing next, and welding is strongest. All three are commonly used.

To bond these metals successfully the surfaces must be chemically and mechanically clean, close contact between the parts to be joined must be maintained, and the proper joining temperature employed. For some alloys and methods, a flux is required.

FORMING: Where hot forming is used to shape brass, forging brass is the favored material, *Table* 6. This alloy can be extruded readily and forged into intricate shapes over a wide range of temperatures.

Frequently, hot working in the initial stage is followed by cold working and annealing later on. Depending on the properties desired in the finished part and the series of secondary fabricating operations, a suitable alloy can be selected from the group of leaded brasses.

CASTING: Most copper-base compositions for casting are mixed brass and bronze with various additions of lead and other minor ingredients.

Copper-base alloys, in addition to being sand cast, can also be plaster molded (melting point below 2000 F), die cast, investment cast and molded in permanent molds.

The development of certain steels as mold materials has made possible a more extensive use of copper-base die casting. The lowest melting-point commercial brasses containing about 60 per cent copper, small additions of lead and tin, plus a trace of aluminum are most suited to die casting. Where strength beyond 50,000-60,000 psi is needed, selenium bronzes are used.

Commonly Used Copper-Base Alloys: Popular alloys for a wide range of design and production needs are classified in six principal groups: high-zinc brasses, low-zinc brasses, leaded brasses, tin brasses, phosphor bronzes and nickel silvers. Commonly used production processes and applications are outlined in *Table* 7.

Brasses containing more than 37 per cent zinc are known as "beta" brasses. They provide high tensile strengths, good hardnesses, good wearing qualities and good hot working properties. Braces in this category can be cold worked to a limited extent.

Brasses containing less than 37 per cent zinc are known as "alpha" brasses. They are ductile and have excellent cold-working properties. Alpha brasses harden during cold work. Since stresses are set up, they should be annealed at moderate temperature, determined by alloy composition and

A number of brasses, bronzes and copper alloys have excellent properties for drawing and forming. Parts shown are used in electrical, refrigeration and air-conditioning equipment

Table 7—Common Fabrication Processes and Applications for Copper-Base Alloys

Alloy	Blanking	Piercing; punching	Stamping	Drawing	Shearing	Forming; bending	Spinning	Coining	Cold forging; heading; upsetting	Cold squeezing; swaging	Roll threading; knurling	Hot forging; pressing	Hot heading; upsetting	Etching	Machining	Applications	Composition
High-Zinc Brasses																	
Cartridge brass	X	X	X	X	X	X	X		X	X				X		Automotive radiator cores, tanks and reflectors; flashlight shells; lamp fixtures; socket shells; screw-base shells; fasteners; pins; rivets; springs; stampings; tubes; ammunition components.	70 Cu, 30 Zn
Yellow Brass	X	X	X	X	X	X	X		X	X	X			X		Automotive radiator cores, tanks and reflectors; flashlight shells; lamp fixtures, screw shells; socket shells; chain; fasteners; grommets; hinges; kick plates; locks; push plates; plumbing accessories; pins; rivets; screws; springs.	65 Cu, 35 Zn
Muntz metal	X				X	X						X	X			Large nuts and bolts; brazing rods; condenser plates; evaporator and heat exchanger tubes; hot forgings; valve stems.	60 Cu, 40 Zn
Low-Zinc Brasses																	
Gilding metal 95%	X	X	X	X	X	X	X	X	X	X				X		Coins; medals; bullet jackets; firing-pin support shells; fuse caps; primers; emblems; jewelry; placques; gold plate base; vitreous enamel base.	95 Cu, 5 Zn
Commercial bronze 90%	X	X	X	X	X	X	X	X	X	X	X	X		X		Screen cloth; escutcheons; kick plates; line clamps; marine. hardware; rivets; screws; screw shells; primer caps and rotating bands for ammunition; ornamental trim; screen wire; vitreous enamel base.	90 Cu, 10 Zn
Red brass 85%	X	X	X	X	X	X	X	X	X	X	X			X		Electrical conduit, screw shells and sockets; fasteners; fire extinguishers; condenser and heat exchanger tubes; flexible hose; pipe; pump lines; radiator cores; dials; etched articles; nameplates; tags.	85 Cu, 15 Zn
Low brass 80%	X	X	X	X	X	X	X	X	X	X	X			X		Medallions and spandrels; dry battery caps; bellows; musical instruments; clock dials; flexible hose; pump lines.	80 Cu, 20 Zn
Leaded Brasses																	
Low-leaded brass	X	X	X	X	X	X									X	Hardware butts, hinge brass and watch backs; ammunition primer bodies; many plumbers' brass goods.	65 Cu, 34.5 Zn, 0.5 Pb
Medium-leaded brass	X	X	X						X		X				X	Butts; gears; nuts; rivets; screws; dials; engravings; instrument plates.	64.5 Cu, 34.5 Zn, 1 Pb
High-leaded brass	X	X	X								X				X	Clock plates and nuts; clock and watch backs; gears; wheels; industrial channel plate.	65 Cu, 33 Zn, 2 Pb
Architectural bronze												X			X	Industrial forgings; valve stems; butts; lock bodies; hinges.	57 Cu, 40 Zn, 3 Pb
Tin Brasses																	
Inhibited admiralty					X	X									X	Industrial condenser, evaporator and heat exchanger tubes; condenser tube plates; distiller tubes and ferrules.	71 Cu, 28 Zn, 1 Sn, 0.5 As (or 0.5 Sb or P)
Naval brass	X	X	X	X	X	X			X			X	X			Aircraft turnbuckle barrels; balls; bolts; nuts; rivets; structural parts; valve stems.	60 Cu, 39.25 Zn, 0.75 Sn
Manganese bronze (A)												X	X			Screens used in paper making and coal mining; automotive clutch disks, pump rods and shafting; balls; valve stems; valve bodies; propellers; welding rods.	58.5 Cu, 39.2 Zn, 1 Fe, 1 Sn, 0.3 Mn
Phosphor Bronzes																	
Phosphor bronze 5%	X	X	X	X	X	X			X		X					Beater bars; bellows; Bourdon tubing; clutch disks; cotter pins; chemical hardware; perforated sheets; textile machinery; welding rods; springs; fuse clips; electrical contacts; switch parts; diaphragms.	95 Cu, 5 Sn, 0.5 max P
Phosphor bronze 8%	X	X	X	X	X	X										Same as phosphor bronze 5% but for more severe service conditions.	92 Cu, 8 Sn, 0.35 max P
Phosphor bronze 10%	X				X	X										Heavy bars and plates for severe compression, good wear and corrosion resistance and articles requiring extra spring qualities or maximum resiliency, particularly in fatigue.	90 Cu, 10 Sn, 1.25 max P
Phosphor bronze 1.25%	X				X	X			X	X						Electrical contacts and springs; flexible hose; diaphragms; pole-line hardware; low friction plates; cold-heading stock; welding rods.	98.75 Cu, 1.25 Sn, tr P
Nickel Silvers																	
Nickel silver 65–18	X	X	X	X	X	X	X		X	X						Hardware; lighting and plumbing fixtures; slide fasteners; camera parts; optical goods.	65 Cu, 17 Zn, 18 Ni
Nickel silver 55–18	X				X	X										Springs; resistance wire; hardware; optical goods; trim; process-industry products.	55 Cu, 27 Zn, 18 Ni
Nickel silver 65–15	X	X	X	X	X	X	X		X	X	X			X		Camera parts; optical goods.	65 Cu, 20 Zn, 15 Ni
Nickel silver 65–12	X	X	X	X	X	X	X		X	X	X			X		Slide fasteners; rivets; screws; optical parts; etching stock; nameplates; decorative trim.	65 Cu, 23 Zn, 12 Ni
Nickel silver 65–10	X	X	X	X	X	X	X		X	X	X			X		Same as nickel silver 65-12.	65 Cu, 25 Zn, 10 Ni

the amount of cold work. These brasses cannot be hardened by heat treating.

Leaded brasses contain from 0.5 to 3 per cent lead to improve machinability. The lead does not affect brass properties except for a slight reduction of malleability and ductility. It does not dissolve in the brass or enter into chemical combination with it. The lead collects as particles throughout the alloy. During machining, these particles assist formation of small chips at the cutting tool. The small chips readily free themselves and prevent fouling or dulling of cutting edges.

Tin brasses contain varying proportions of copper and zinc with up to 1 per cent tin. Tin increases tensile strength with a slight sacrifice of working properties, particularly hot working.

Phosphor bronzes are copper-tin alloys with small amounts of phosphorus to produce metal with great resiliency, fatigue endurance and hardness. The development of phosphor bronzes provides materials with a low coefficient of friction, high resistance to shock, wear and abrasion, and good cold-working characteristics.

Nickel silvers are brasses with 10 to 18 per cent nickel. They provide malleable, ductile and inherently tough silvery-white alloys. They are particularly well suited for etching, enameling, and silver and chromium plating. Plating does not require preplate or flash coating because high polishes on nickel silvers are adequate for a smooth, adhesive and uniform plate.

HIGH-ZINC BRASSES: The principal high-zinc brasses include cartridge brass, yellow brass and Muntz metal.

Cartridge brass provides excellent tensile strength and good ductility. *Yellow brass* provides excellent tensile strength, good ductility and bright yellow color. When cartridge brass and yellow brass are deep drawn, definite grain sizes should be specified to assure high polish finish for the final product. *Muntz metal* has high strength and low ductility. It has excellent hot-working properties and limited facility for cold work. For these reasons Muntz metal is not recommended for spinning, upsetting or drawing. The comparatively low melting point of Muntz metal permits good spot or gas welds.

LOW-ZINC BRASSES: The principal low-zinc brasses include gilding metal 95%, commercial bronze 90%, red brass 85%, and low brass 80%.

Gilding metal 95% has a rich bronze color. *Commercial bronze* 90% is technically a brass that is named because of its typically bronze color. It has excellent cold-working properties. *Red brass* 85% provides a rich golden color material with excellent cold-working properties. *Low brass* 80% is an alloy with a pleasing light golden color, somewhat more reddish than yellow brass.

LEADED BRASSES: Leaded brasses can be hot worked if they are given mechanical support. At high temperatures the molten lead in these alloys tends to produce breakage during hot rolling or piercing operations. Leaded brasses have relatively poor cold working properties which are roughly inversely proportional to lead content. These alloys have been developed particularly for use where machinability is a prime consideration. Machinability of leaded brasses generally increases with lead contents up to 3 per cent—with greatest improvement shown for the initial 1 per cent.

Leaded brasses include: low leaded brass, medium leaded brass, high leaded brass, architectural bronze and free-cutting brass.

Low-leaded brass is essentially a yellow brass with 0.5 per cent lead replacing a like amount of zinc. It provides suitable properties for cold working, including bending and flanging. *Medium-leaded brass* contains 1 per cent lead; otherwise it is similar to low-leaded brass. *High-leaded brass* is also a yellow brass with 2 per cent lead. It is somewhat less tough and strong than medium leaded brass. Machinability is excellent and cold-working properties fair. *Architectural bronze* contains 3 per cent lead. It is produced principally in extruded shapes.

Free-cutting brass will withstand moderate bending and forming. It is the most widely used copper-base alloy for automatic screw-machine work. This low-cost alloy with a pleasing yellow color gives a fine machined finish that is suitable for plating. It provides an economical material for drilling, forming, knurling, milling, reaming, tapping, threading and turning.

TIN BRASSES: The principal tin brasses include inhibited admiralty, naval brass and manganese bronze (A). These alloys, generally speaking, have been developed particularly for marine use.

Inhibited admiralty is suitable for forming and bending and machine operations. *Naval brass* is considered an ideal alloy for marine propeller shafting and hardware. *Manganese bronze (A)* is a tin brass providing high tensile strength. It is excellent for hot working and moderately suited for cold work.

PHOSPHOR BRONZES: Principal alloys in the phosphor bronze group are phosphor bronze 5%, phosphor bronze 8%, phosphor bronze 10% and phosphor bronze 1.25%.

Phosphor bronze 5% contains 95 per cent copper and 5 per cent tin with a maximum of 0.35 per cent phosphorus. *Phosphor bronze* 8% provides good hardness and stiffness combined with adequate ductility to withstand unusually severe forming. It provides greater spring life than phosphor bronze 5%. *Phosphor bronze* 10% is generally indicated for designs requiring exceptional spring quality and resistance to wear after fabrication. *Phosphor bronze* 1.25% can be more easily worked than other phosphor bronzes.

NICKEL SILVERS: Copper-base alloys in the nickel silver group include nickel silver 65-18; nickel silver 55-18; nickel silver 65-15; nickel silver

65-12; and nickel silver 65-10.

Nickel silver 65-18 has excellent malleability and ductility. It can be fabricated by all processes and readily cold worked. *Nickel silver* 55-18, like nickel silver 65-18, provides high fatigue strength, with less malleability. *Nickel silver* 65-15 has properties similar to nickel silver 65-18, but provides a whiter color. *Nickel silver* 65-12 has very good ductility characteristics. *Nickel silver* 65-10 provides properties similar to those of nickel silver 65-12 and is generally used for the same range of applications.

Other Alloys: Several alloys not included in the previous classification are worthy of note.

BERYLLIUM COPPER, with 2 per cent beryllium and 0.3 per cent cobalt, is an age-hardening alloy which can be worked in the soft stage. Then by low-temperature heat treatment, high hardness and tensile strength can be imparted. This alloy exhibits good fatigue resistance and wear resistance and ease of formability. It may also be cast by investment, plastic and pressure methods. Applications include electrical contacts, springs and electrical terminals.

SILICON BRONZES are of two types. High-silicon bronzes containing about 3 per cent silicon have excellent capacities for hot and cold working and joining. Common fabricating processes include blanking, forming and bending, hot forging and upsetting.

Low-silicon bronze, containing from 0.8-1.5 per cent silicon, are also widely used. These alloys are recommended for hydraulic pressure lines, heat-exchanger tubes, marine hardware and propeller shafts on vessels.

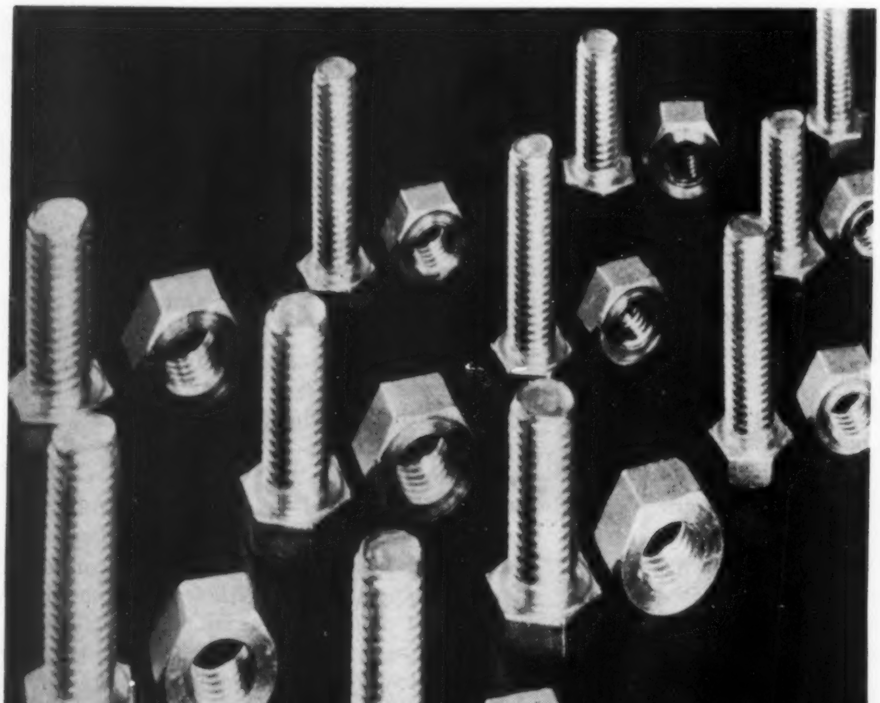
This group of alloys has superior strength and corrosion resistance, high fatigue resistance and is nonmagnetic. Depending on the quantity of silicon, they exhibit slightly different workability, machinability and hardness values.

ALUMINUM BRONZE alloys containing up to 15 per cent aluminum are coming into wide use. Most of the commercial varieties have 4-11 per cent aluminum and various additions of iron, nickel, manganese and silicon or other alloys.

By choosing the composition, mechanical properties can be varied from moderately strong with excellent ductility up to high-strength alloys with fair ductility.

Procedures have been developed for successfully casting aluminum bronzes in centrifugal and die-casting machines. Depending on the alloy, these metals may be readily cold and hot worked. Certain single-phase alloys are somewhat stiffer than phosphor bronzes, and drawing operations are limited to simple shapes. Major applications of the aluminum bronzes are based on their good mechanical properties, chemical resistance, retention of strength at high temperatures and high resistance.

PROPRIETARY ALLOYS have been developed by individual brass mills to meet unusual production conditions. These have strength, age-hardening qualities, machinability or other characteristics desired for certain applications.



Silicon bronze is often used for bolts and nuts because of its high strength — approximating that of steel. Easily cold and hot worked, silicon bronze is extremely tough and has superior corrosion resistance

Production Characteristics

Wrought Aluminum Alloys

Heat treatment • Cold forming
Machinability • Extrusion • Forging
Welding • Brazing • Soldering • Finishing

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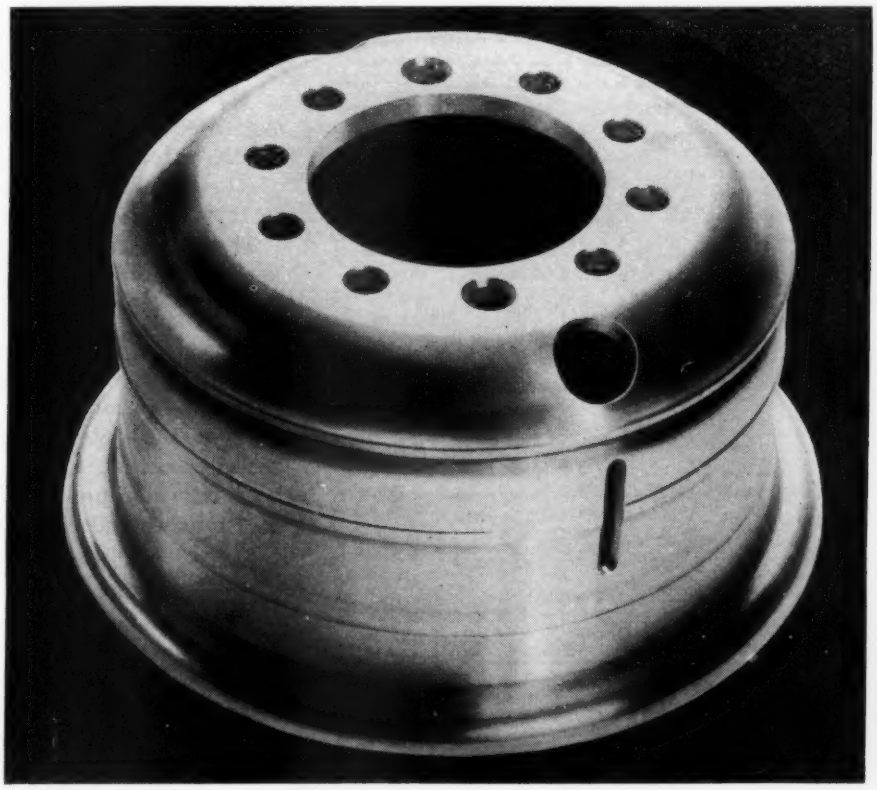
FOR THE designer contemplating the use of wrought aluminum alloys, a wide variety of alloys and products is available from which to select the most suitable material, *Tables* 1 and 2. This article offers a comprehensive description of the preferred alloys for particular production operations.

A natural division of the wrought aluminum alloys is into nonheat-treatable alloys and heat-treatable alloys. With the nonheat-treatable alloys the various tempers are produced by strain hardening. The heat-treatable alloys can be changed to a desired temper with solid-solution and precipitation heat treatments.

NONHEAT-TREATABLE ALLOYS: This group of alloys includes all grades of commercial and higher purity aluminum, plus alloys of intermediate strength. These wrought alloys are characterized by general low cost, low to moderate strengths, good formability and high resistance to corrosion.



Bus and truck wheel is machined from an aluminum forging. Weight of the disk wheel is 48 pounds, from 32 to 50 pounds less than corresponding steel wheels

Most of these alloys are produced by the addition of two major alloying elements to aluminum—manganese and magnesium. Manganese is the chief addition to 3003 alloy, while both magnesium and manganese are added to 3004 alloy. Alloys 5052 and 5056 contain magnesium with small amounts of chromium or chromium and manganese.

Heat-treatable Alloys: The heat-treatable wrought aluminum alloys contain alloying additions that are soluble in considerable amounts at elevated temperatures and to a much smaller degree at room temperature. The additions are generally somewhat in excess of the quantity soluble at the highest temperature at which the alloy can be heat treated safely. In addition to the soluble alloying elements, the heat-treatable alloys generally contain one or more insoluble elements, which add to the strength of the product and aid in control of the grain structure or other metallurgical characteristics.

The heat-treatable alloys generally are grouped under four classifications according to the principal alloying elements employed to produce susceptibility to heat treatment. These four classifications are: (1) aluminum-magnesium-silicon alloys; (2) aluminum-copper alloys, including aluminum-copper-magnesium and aluminum-copper-magnesium-silicon alloys; (3) aluminum-zinc-magnesium-copper alloys; and (4) miscellaneous alloys.

The first three classifications include the general-purpose structural materials whose strengths increase in the order named, while the fourth classification includes alloys of several types which are used for special purposes such as free machining and elevated temperature applications.

Alclad Products: An important group of wrought aluminum products is designated as Alclad products. These are employed where maximum resistance to corrosion is required. Alclad products consist of an aluminum alloy core covered on one or both surfaces with a thin layer (or layers) of corrosion-resistant aluminum or aluminum alloy, generally ranging from 2½ to 10 per cent of total thickness of the product. The coating and core alloy combinations are selected so that under corrosive conditions the coating is anodic to the core and electrolytically protects the core when exposed at cut edges or by abrasion or corrosion.

New Alloy Designations: Ease of identifying the principal alloying constituent in aluminum alloys has been advanced with the new alloy designation system for wrought aluminum alloys recently put into effect by the Aluminum Association.

To designate wrought aluminum alloys, a four-digit index system is used. The first digit indicates the alloy group. Thus 1XXX indicates aluminum of 99 per cent minimum or greater; 2XXX indicates an aluminum alloy in which copper is the major alloying element; 3XXX is an aluminum alloy with manganese as the major alloying element; 4XXX indicates silicon is the major alloying element; 5XXX is alloyed principally by magnesium; 7XXX by zinc; and 8XXX indicates other major alloying elements. Although most aluminum alloys contain several alloying elements, only one group, 6XXX for alloys with magnesium and silicon as the major alloying elements, designates more than one alloying element.

In the 1XXX group for aluminum of 99 per cent minimum and greater, the last two of the four digits in the designation indicate the minimum aluminum percentage. These digits are the same as the two digits to the right of the decimal point in the minimum aluminum percentage when it is expressed to the nearest 0.01 per cent. In the 2XXX through 8XXX alloy groups, the last two of the four digits in the designation serve only to identify the different alloys in the group.

The second digit in the new alloy designations generally indicates alloy modifications.

Production Characteristics: The wrought aluminum alloys, *Table* 3, are extremely workable by most cold-forming and hot-forming methods, can be machined at high speeds with fast rates of metal removal, can be formed by both hot and cold-extrusion processes, are easily joined by welding, brazing and riveting, and can be finished with a myriad of polished, brushed and plated surfaces.

Cold forming: While most of the wrought aluminum alloys can be cold formed with relative ease, selection of the proper alloy and temper is of paramount importance when designing with aluminum. The cost of the ultimate product is governed by this choice. The wrought aluminum alloys which can

Table 1—Wrought Aluminum Alloys

Alloy*	Nominal Composition (%, Al remainder)					
	Cu	Si	Mn	Mg	Zn	Others
EC	99.45% min aluminum					
1100	99% min aluminum					
3003†	...	...	1.2	...	...	...
3004†	...	...	1.2	1.0	...	...
2011	5.5	...	...	...	...	0.5 Pb, 0.5 Bi
2014†	4.4	0.8	0.8	0.4	...	...
2017	4.0	...	0.5	0.5	...	...
2018	4.0	...	...	0.6	...	2.0 Ni
2218	4.0	...	...	1.5	...	2.0 Ni
2024†	4.5	...	0.6	1.5	...	...
4032	0.9	12.2	...	1.1	...	0.9 Ni
4043	...	5.0	...	...	...	...
5050	...	...	...	1.2	...	...
6951	0.25	0.35	...	0.6	...	...
6151	...	1.0	...	0.6	...	0.25 Cr
5052	...	...	...	2.5	...	0.25 Cr
6053	...	0.7	...	1.3	...	0.25 Cr
5154	...	...	...	3.5	...	0.25 Cr
5056	...	...	0.1	5.2	...	0.1 Cr
6061	0.25	0.6	...	1.0	...	0.25 Cr
6062	0.25	0.6	...	1.0	...	...
6063	...	0.4	...	0.7	...	...
7072	...	...	...	...	1.0	...
7075†	1.6	...	...	2.5	5.6	0.3 Cr

* Heat-treated symbols have been omitted since composition does not vary for different heat-treatment practices.

† The Alclad form of these alloys consist of a "core" of the basis alloy coated with pure aluminum or a suitable alloy.

be used are numerous, and each can be supplied in several tempers.

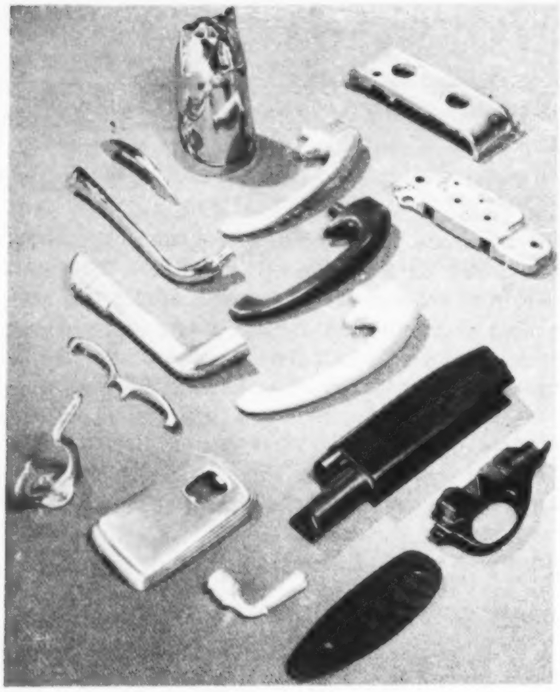
Both heat-treatable and nonheat-treatable aluminum alloys are adaptable for cold working, although the non..eat-treatable alloys are generally easier to form. Among the nonheat-treatable alloys commonly used for applications where cold working is the prime consideration, are 1100, 3003, 3004, 5052 and 5154. Among the heat-treatable alloys more commonly used in applications involving cold forming are alloys 2014, 2024, 6061, 6062, 6063 and 7075.

Size, shape and operating (or service) conditions are a few of the factors that affect the choice of material. Commercially pure aluminum, in annealed condition, is ductile and can be drawn to greater depths than brass, copper or steel. Its low strength, however, precludes its use for many

Table 2—Properties, Characteristics and Uses of Wrought Aluminum Alloys

Alloy	Condition	Tensile Strength (1000 psi)	Yield Strength[1] (1000 psi)	Elongation in 2 in. Sheet[2] (%)	Elongation in 2 in. Rod[3] (%)	Brinell Hardness[4]	Resistance to Corrosion[5]	Typical Uses	Chief Characteristics	Alloy
1100-O	Annealed	13	5	35	45	23	A	Sheet metal work, spun hollow ware, decorative parts	Excellent forming qualities, resistance to corrosion, weldability, low cost	1100
1100-H18	Hard	24	22	5	15	44	A			
3003-O	Annealed	16	6	30	40	28	A	Chemical equipment, tanks	Workability, weldability, resistance to corrosion, low cost	3003
3003-H18	Hard	29	27	4	10	55	A			
Alclad 3003-O	Annealed	16	6	30	40	..	A	Heat - exchanger tubes, chemical equipment	Same as 3003; has higher resistance to perforation under severely corrosive conditions	Alclad 3003
Alclad 3003-H18	Hard	29	27	4	10	55	A			
3004-O	Annealed	26	10	20	25	45	A	Special sheet - metal work	Higher strength than 3003, good resistance to corrosion	3004
3004-H38	Hard	41	36	5	6	77	A			
2011-T3	Heat-treated	55	48	..	15	95	D	Screw-machine products	Good machinability, "free" cutting, good mechanical properties	2011
2011-T8	H. T., Cold-wkd. & Aged	59	45	..	12	100	C[6]			
2014-T4	Heat-treated	62	42	..	20	105	C[6]	Heavy - duty forgings, airplane fittings, structural members	High strength and hardness, moderate cost	2014
2014-T6	H. T. & Aged	70	60	..	13	135	C[6]			
Alclad 2014-T3	Heat-treated	63[7]	40[7]	20	..	..	A	Bridges, heavy - duty structures	High strength with high resistance to corrosion, moderate cost	Alclad 2014
Alclad 2014-T6	H. T. & Aged	68[7]	60[7]	10	..	..	A			
2017-T4	Heat-treated	62	40	..	22	105	C[6]	Screw-machine products, fittings	Good machinability ,relatively high strength	2017
2117-T4	Heat-treated	43	24	..	27	70	C	Rivets	Highest strength rivet alloy requiring no heat treatment by user	2117
2018-T61	H. T. & Aged	61	46	..	12	120	C	Aircraft-engine cylinder heads	Good strength at elevated temperatures	2018
2024-T3	Heat-treated	70	50	18	..	120	C[6]	Aircraft, truck wheels, caul plates	High strength with adequate workability	2024
2024-T36	H. T. & Cold-worked	72	57	13	..	130	C[6]			
Alclad 2024-T3	Heat-treated	65[7]	45[7]	18	..	..	A	Aircraft, truck bodies	Combines strength of 2024 with high resistance to corrosion, good appearance	Alclad 2024
Alclad 2024-T36	H. T. & Cold-worked	67[7]	53[7]	11	..	..	A			
4032-T6	H. T. & Aged	55	46	..	9	120	C	Forged pistons	Low coefficient of thermal expansion, high strength	4032
5050-O	Annealed	21	8	24	..	36	A	Decorative refrigerator parts, general-purpose tubing	Intermediate strength, good finishing characteristics	5050
5050-H38	Hard	32	29	6	..	63	A			
6151-T6	H. T. & Aged	48	43	..	17	100	B	Intricate forgings, machine and automotive parts	Excellent forgeability, good strength, resistance to corrosion	6151
5052-O	Annealed	27	13	25	30	45	A	Sheet-metal parts, home appliances, transportation applications	Good finishing characteristics, excellent resistance to corrosion, good strength	5052
5052-H38	Hard	42	37	7	8	85	A			
6053-T4	Heat-treated	30	20	..	21	62	A	....	....	6053
6053-T6	H. T. & Aged	37	32	..	13	80	A			
5154-O	Annealed	35	15	25	..	..	A	....	....	5154
5154-H34	Hard	42	33	12	..	..	A			
5154-H38	Hard	48	39	8	..	..	A			
5056-O	Annealed	42	22	..	35	65	A	....	....	5056
5056-H38	Hard	60	50	..	15	100	B			
6061-T4	Heat-treated	35	21	22	25	65	A	Truck bodies, structures, pipe	Good strength and workability, high resistance to corrosion	6061
6061-T6	H. T. & Aged	45	40	12	17	95	A			
6063-T5	Extruded & Aged	27	21	12	..	60	A	Windows, irrigation pipe, standard pipe	High resistance to corsion, pleasing appearance, adequate strength, low cost	6063
7075-T6	H. T. & Aged	83[8]	73[8]	11	11	150	C	Aircraft, keys	Very high strength and hardness	7075
Alclad 7075-T6	H. T. & Aged	76	67	11	..	..	A	Aircraft	Very high strength and resistance to corrosion	Alclad 7075

[1]Stress at which material exhibits 0.2 per cent permanent set.
[2]Thickness, $\frac{1}{16}$-inch.
[3]Diameter, ½-inch.
[4]500-kg load, 10-mm ball.
[5]Atmospheric. An "A" rating is highest. However, under many conditions, alloys rated "D" may be used with entirely satisfactory results, or alloys rated "A" may require protection.
[6]In thicknesses of about ⅛-inch and over, these alloys in the -T3, -T4 and -T36 tempers have a "D" rating.
[7]Sheet over 0.064-inch thick will have slightly higher tensile and yield strengths.
[8]Strengths will be higher for extrusions.



Finishes used for aluminum parts can include chrome plating, anodic oxide (Alumilite) coatings—both natural and colored, and mechanical finishes

items. Other alloys are drawn from annealed blanks or metal of an intermediate temper, depending upon the severity of the draw and type of tools.

Most products are made from alloys 1100 or 3003 because of the ease with which these alloys can be formed. Their strength has been found to be adequate, and they are also lowest in metal price. Parts subjected to hard usage, wear, high temperatures or pressures are made from 3004, 5052 or one of the heat-treatable alloys.

If the part is to be anodically treated, some other alloy, such as 5050 or 5357, may be selected. Chemical composition, and fabricating controls used in producing an alloy, have a strong effect on the anodic-oxidation characteristics of that alloy. Cold-forming characteristics of a range of aluminum alloys are outlined generally in *Table* 3.

Machinability: An outstanding characteristic of the wrought aluminum alloys is the ease with which they can be machined. The principal factors affecting relative machinabilities are chemical composition and temper. In *Table* 4, commercial wrought aluminum alloys are segregated into groups depending upon whether they are heat-

Table 3—Fabrication Characteristics

Alloy	Cold Work*	Machinability*	Brazing†	Weldability† Gas	Arc	Resistance	Pressure	Soldering†
1100-O	A+	B	A	A	A	B	A	A
1100-H18	B—	B	A	A	A	A	A	A
3003-O	A+	B	A	A	A	B	A	A
3003-H18	C+	B	A	A	A	A	A	A
Alclad 3003-O	A+	B	A	A	A	B	A	A
Alclad 3003-H18	C+	B	A	A	A	A	A	A
3004-O	A+	B	B	A	B	B	A	B
3004-H38	C+	B	B	B	A	A	B	B
2011-T3	C—	A	D	D	D	D	D	D
2011-T8	D	A	D	D	D	D	D	D
2014-T4	C	A	D	B	B	B	C	D
2014-T6	C—	A	D	D	B	B	D	D
Alclad 2014-T3	C	A	D	D	B	B	C	D
Alclad 2014-T6	C—	A	D	D	B	B	C	D
2017-T4	C	A	D	D	B	A	D	D
2117-T4	B—	A	D	D	C	D	..	..
2018-T61	....	A	D	D	B	B	D	D
2024-T3	C—	A	D	D	B	B	C	D
2024-T36	D+	A	D	D	B	B	C	D
Alclad 2024-T3	C	A	D	D	B	B	C	D
Alclad 2024-T36	C—	A	D	D	B	B	C	D
4032-T6	....	C	D	D	B	C	C	D
5050-O	A+	B	B	A	A	B	A	B
5050-H38	C+	B	B	A	A	A	B	B
6151-T6	....	B	B	A	A	A	C	B
5052-O	A+	B	C	A	A	B	A	C
5052-H38	C+	B	C	A	A	A	B	C
6053-T4	B—	B	A	A	A	A	C	B
6053-T6	C+	B	A	A	A	A	C	B
5154-O	B+	C	D	C	A	B	A	D
5154-H34	B+	C	D	C	A	B	C	D
5154-H38	B+	C	D	C	A	A	C	D
5056-O	A	B	D	C	A	B	A	D
5056-H38	B—	B	D	C	A	A	C	D
6061-T4	B	B	A	A	A	A	C	B
6061-T6	B-	B	A	A	A	A	C	B
6063-T5	B	B	A	A	A	A	C	B
7075-T6	D	A	D	D	D	B	D	D
Alclad 7075-T6	D+	A	D	D	D	B	D	D

*A—excellent; B—good; C—fair; D—poor. Ratings are based on aluminum-base alloys as a group and are not to be used in comparison with other metals.

†A—generally weldable (or suitable for brazing or soldering) by all commercial procedures and methods. B—weldable with special techniques or on specific applications which justify preliminary trials or testing to establish procedures and performance. C—limited weldability because of crack sensitivity or loss in resistance to corrosion and in mechanical properties. D—no commonly used welding methods have so far been developed.

treatable or nonheat-treatable. Within each group, the alloys are arranged in the approximate order of their relative machinability when each alloy is considered to be in its most machinable condition.

Among the wrought alloys, those which are heat treated to improve their mechanical properties generally have good machining characteristics. Alloy 2011 is the most free machining of the wrought aluminum alloys; it can be machined at high speeds with heavy feeds and small rake angles; chips are small and finish is excellent. The nonheat-treatable alloys are softer than the heat-treatable alloys and, therefore, can be machined more readily by the tools having relatively large rake angles. Generally, the greater the amount of strain hardening prior to machining, the better the machining characteristic of the nonheat-treatable alloys.

Extrusion Characteristics: Aluminum alloys used for extrusion can be divided generally into four classes. In the first class are readily extrudable alloys which depend for their use on good workability. Such alloys are 1100 and 3003; a typical example of their use would be for trim molding where short-radius bends are required. In extrusion, these alloys require relatively low extrusion pressure and can be extruded at high speeds even for hollow sections. Generally, production rate is regulated by the operation of handling equipment rather than any extrusion limitation.

In the second class is a group of alloys whose main reason for use is maintenance of good appearance in service, either with or without an anodic coating. The leading alloy in this group is 6063, and it is the favorite for trim molding and many architectural applications. A new alloy in this group is X4543. This alloy contains silicon as its principal alloying component and is applicable for components used outdoors where intermediate strength and good forming characteristics are required. On anodic oxide (Alumilite) treatment this alloy acquires a neutral gray oxide coating. All of these alloys are readily extrudable and require relatively low pressure, although slightly more than the first group. Like the first class, they are limited in their production rate by handling equipment.

Table 4—Relative Machinability

Machinability	Heat-Treatable Alloys	Nonheat-Treatable Alloys
Highest	2011	
Excellent	2017, 2117 2024, 2014 7075, 2025 2018, 2218	5056
Good	6061, 6062 6053, 6063 6151, 4043*	5154, 5052 5050, 3004 3003, 1100 1060, EC

* Alloy cuts freely but tools wear excessively if not tipped with cemented carbides.

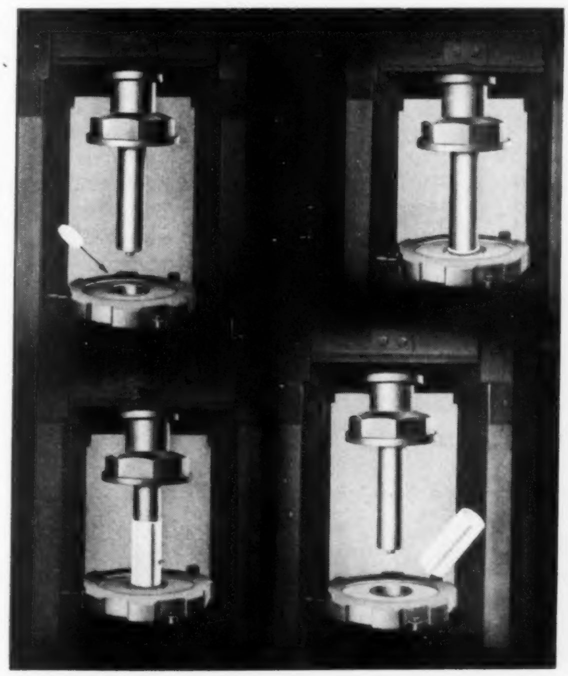
Possibly a subdivision of the second group of alloys would be the 2EC alloy because of its similarity in fabricating characteristics and composition. The principal advantage of this alloy is that it provides a conductor alloy with high strength.

For the third class are those alloys with medium-strength characteristics such as 6061 and 6062. These alloys can be extruded at reasonable rates, and although they require higher pressures than the previous groups, they do not cause any difficulty during extrusion. The alloys in their heat-treated tempers are used primarily for transportation applications, such as railroad cars and truck bodies.

The last group consists of high-strength alloys such as 2014, 2024 and 7075. These alloys, used primarily for aircraft and other structural applications, are in some cases rather difficult to extrude and require high-capacity presses capable of exerting pressures between 100,000 and 150,000 psi to the ingot to be extruded. As a class, this type of alloy cannot be extruded at high rates and thus has been the subject of much experimental work to improve its extrusion characteristics.

In addition to the alloys used for the production of extruded products, those of the aluminum-magnesium type such as 5052, 5005 and 5050 are

Impact extrusion, a process particularly suited to aluminum, produces deep parts. A slug of metal is extruded upward over the punch as the punch travels downward. On the return upward stroke, the shell adheres to the punch because of shrinkage. It is then stripped off by a stationary stripper bridge



used for the production of blooms for the manufacture of drawn tubes. These alloys are not generally employed in the as-extruded condition because they have low mechanical properties, but they find many uses when cold worked. Most of the other extrusion alloys can also be used to fabricate other types of drawn tube.

Impact Extrusion: One of the methods of producing engineered aluminum parts which is growing in importance is the impact-extrusion process. Wrought aluminum alloys best suited for impact extrusion are also generally recommended for cold heading and other cold forging operations.

For practical reasons, alloys used for aluminum impact extrusions are largely confined to 1100, 6151, 6061 and 2014. Many of the other wrought alloys can be extruded, but for most requirements an adequate range of mechanical properties is obtained with these four alloys.

Commercially pure aluminum (1100) in the work-hardened condition meets the strength requirements for many applications of extruded parts. Alloys 6151 and 6061 are used when additional strength is required. Highest strength requirements can be met by the use of either 2014 or 7075 alloys, heat treated to the -T6 temper. In general, these alloys are limited to the thicker sections and each application requires special attention.

Forging: Most wrought aluminum alloys can be forged. Choice of an alloy generally rests on its strength properties. Since the principal reason for producing an aluminum forging is to achieve a high strength-to-weight ratio, difficult-to-forge (and therefore more expensive) alloys are sometimes used. In most cases, however, forgeability of an alloy should have a basic influence on the alloy chosen.

Alloy 2014 is the most widely used of the high-strength forging alloys. Recommended for general structural applications, this alloy provides high tensile and yield strengths, good hardness, ductility, and high fatigue strength. The alloy also has relatively good forging qualities and is readily machined.

Alloy 6061 surpasses all other commercial alloys in forgeability, and its machining characteristics are good. It is also used where good welding or brazing qualities are desired. These production advantages are combined with moderately good mechanical properties and excellent resistance to corrosion. This alloy is used generally where cost is more important than extremely high strength.

Alloy 7075 is a "superstrength" aluminum alloy. Being more difficult to forge, parts produced in 7075 are generally more expensive. This alloy is specified only where extremely high strength is of sufficient importance to justify its higher cost.

Alloy X7079 is the newest of the aluminum forging alloys. It joins 7075 in the high strength category. Alloy X7079 offers more uniform properties in thick sections. In addition, it is less sensitive to quenching in thicker sections than 7075.

Alloys 4032, 2218, 2618 and 2018 retain their strength better at elevated temperatures than the other alloys that have been discussed. Parts that must undergo repeated loading at high temperatures, such as pistons and cylinder heads for aircraft engines and pistons for heavy-duty diesels, are typical applications. Choice among these alloys depends upon the particular combination of thermal and mechanical properties desired.

Alloy 2025 is employed primarily for aircraft propellers. Its good forging characteristics make it desirable for impellers used in superchargers for reciprocating engines and turbines, and similar parts.

Welding and Brazing: Most wrought aluminum alloys can be brazed or welded by all popular methods, including torch, arc and resistance welding. Some alloys, however, can be more easily welded by particular methods. An indication of the relative weldability of the different alloys is presented in *Table* 3.

Some of the strength characteristics and ductility of the more weldable alloys are indicated in *Table* 5.

Joining of aluminum alloy components fabricated from sheet is facilitated in many cases by the use of a special brazing sheet. In this product, a thin coating of filler metal is bonded to the surface of the sheet on either one or both sides. Parts are formed by bending, drawing or hammering as may be required. The coating forms with the parent metal to the shape of the piece and is in position for brazing with no further work.

Soldering: Soldering can be successfully used

Table 5—Strength and Ductility of Welded Butt Joints*

— Materials —		Tensile Strength			Free-Bend
		Parent Material		Weld	
Parent Material Alloy	Filler Metal Alloy	Annealed (1000 psi, min)	Heat Treated (1000 psi, min)	(1000 psi, ave)	Elongation (%, ave)
Nonheat-treatable alloys					
1100	1100	11	..	13.4	54
3003	1100	14	..	16	58
3004	3004	23	..	27.5	26
5052	5052	25	..	28.2	39
5154	5154	30	..	33.3	39
5056	5056	35	..	38.3	31
X5356	X5356	35	..	40.2	34
Heat-treatable alloys (not heat treated after welding)					
2014-T6	4043	..	64	33.9	9
6061-T6	4043	..	42	27.2	16
6062-T6	4043	..	42	27.2	16
6063-T5	4043	..	22	20	..
6063-T6	4043	..	32	20	..
6063-T83	4043	..	33	20	..
6063-T831	4043	..	28	20	..
6063-T832	4043	..	40	20	..
Heat-treatable alloys (heat treated and aged after welding)					
2014-T6	4043	..	64	51.5	5
6061-T6	4043	..	42	43.5	11
6062-T6	4043	..	42	43.5	11

* Made by the argon-shielded tungsten-arc or the argon-shielded consumable-electrode method.

for joining any of the commercial forms of virtually all aluminum alloys. Generally, soldering becomes more difficult as the amount of magnesium or silicon in the alloy increases. Relative ease of soldering the various wrought alloys is indicated in *Table* 3.

Finishing: With the strong effect of styling on product design, the multitude of finishes possible with aluminum have become one of the metal's prime design considerations. Since the aluminum alloy used and its temper sometimes limit the type of finish that can be applied, the designer should consider the finish in his material specification as carefully as he considers such basic factors as the mechanical properties.

Wrought (and cast) aluminum alloys can be finished by mechanical means (polishing, buffing and barrel burnishing), bright dipping, electrobrightening, chemical coating, anodic oxidation, electroplating, painting and lacquering, and by enameling.

The suitability of the different aluminum alloys used for each of these finishing methods is summarized as follows:

ANODIC OXIDATION: The Alumilite treatment provides a principal method for applying oxide finishes to aluminum products. These coatings increase abrasion and corrosion resistance of aluminum and have the advantage of being integral with the surface of the metal. In addition, anodic oxide coatings can be colored in a wide range of metallic hues.

While all aluminum alloys can be anodically coated, the composition of the alloy has an appreciable effect on the thickness, abrasion resistance and other characteristics of the oxide coating. Composition also influences the color and uniformity of appearance of the coating.

For example, some silicon-bearing alloys induce a brown or gray color in the coating; copper in some alloys will induce a golden color; and manganese produces a brownish tint. These and other effects make the use of an anodic coating on an aluminum alloy an important design choice. Because of the many variables involved, data on these anodic finishes cannot be summarized in condensed tabular form.

ELECTROBRIGHTENING: Many aluminum alloys can be given a pleasing finish by electrobrightening. This involves electrolytic treatment in special electrolytes. In general, the higher purity alloys and 1100 alloy respond best to this type of treatment. Good results are also possible with the aluminum-magnesium alloys. Electrobrightening is not suitable for use on the high-strength alloys containing appreciable amounts of copper and silicon.

BRIGHT DIPPING: For the chemical brightening of a wide variety of aluminum alloys, a bright-dip process (Alcoa R5) is available. The bright-dip process is convenient and economical to use for many applications.

ELECTROPLATING: Electroplating of aluminum

alloys is both practical and commercially feasible. In general, however, aluminum alloys do not respond to the cleaning and etching procedures ordinarily used to prepare other metals for electroplating. When suitable preparatory procedures are used, aluminum can be satisfactorily electroplated with such metals as brass, chromium, cadmium, nickel, copper, zinc, tin and others.

ETCHING: Most aluminum alloys can be etched by alkaline solution to produce a matte finish. Special procedures must be used with a few alloys. The high-purity alloys, for example, respond poorly to alkaline etches in producing a uniform matte surface.

CHEMICAL CONVERSION COATINGS: Chemical conversion coatings provide an execellent base for paint, lacquer or enamel on most wrought alloys. These coatings (such as the Alrok treatment) are inexpensive and easy to apply. They are generally used for nondecorative application, but some recently developed chemical-conversion treatments appear to have decorative possibilities for architectural applications.

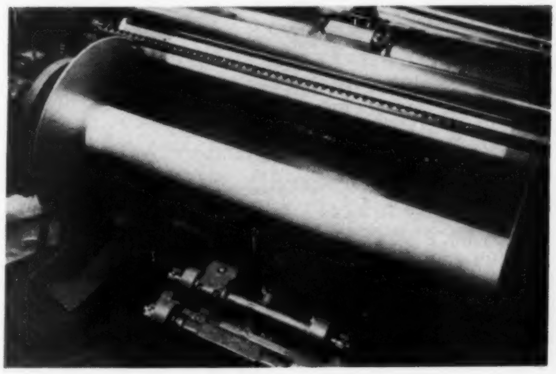
Although chemical-conversion treatments are generally applicable to all wrought aluminum alloys, special variations in techniques are required for different alloy types.

MECHANICAL FINISHING: All wrought alloys can be mechanically finished to produce functional or decorative effects. An approximate indication of the polishing or buffing characteristics of an alloy is its hardness—the harder, the better.

PORCELAIN ENAMELING: All wrought alloys can be porcelain enameled with the exception of the copper-bearing alloys. Alloys 6061 and 6063 require extra surface treatments.

High temperatures required for firing vitreous enamels restrict the use of many of the high-strength alloys because of their melting points. For 6061 alloy, however, the firing produces a heat-treating effect, whereas in the nonheat-treatable alloys the firing causes softening by annealing.

An extrusion of either 6063-T5 or 6061-T6 aluminum alloy is used for this loom beam barrel. Only 2/3 as heavy as wood, traditionally used, the barrel is permanent and lightweight



Production Characteristics

Cast Aluminum Alloys

Castability • Machinability
Weldability • Finishing

By G. W. Birdsall
Reynolds Metals Co.
Louisville, Ky.

Table 1—Aluminum Casting Methods and Alloys

1. **Sand casting** is the oldest and most familiar method of casting. Here the castings are made by pouring molten aluminum into either green sand molds or molds made of baked sand. Suitable alloys include:

12	142	B214	356
43	A 142	F214	A612
108	195	220	Almag 35
112	212	319	.....
113	214	355	.....

2. **Permanent-mold casting** employs molds made from cast iron or steel. These molds are usually 1 to 2 inches in thickness to provide sufficient thermal capacity to assure rapid chilling of the cast metal. Semipermanent mold casting combines steel or iron molds with sand cores to produce more intricate and complex shapes. Alloys include:

43	D132	B214	C612
A108	138	319	6-6
113	142	333	Almag 35
C113	A142	355	.....
122	B195	356	.....
A132	A214	382	.....

3. **Die Casting** employs pressure to force the molten metal into the cavities in a steel die. Alloys include:

13	85	218	380
A13	C214	360	A380
43	L214	A360	384

4. **Other processes,** of more limited application, include centrifugal casting, investment or precision casting, plaster-mold and shell-mold casting.

SINCE certain aluminum alloys are better suited for a particular casting process than others, a brief resume of aluminum casting methods and factors involved may set the stage for actual alloy selection. Basic casting methods and suitable alloys are outlined in *Table* 1.

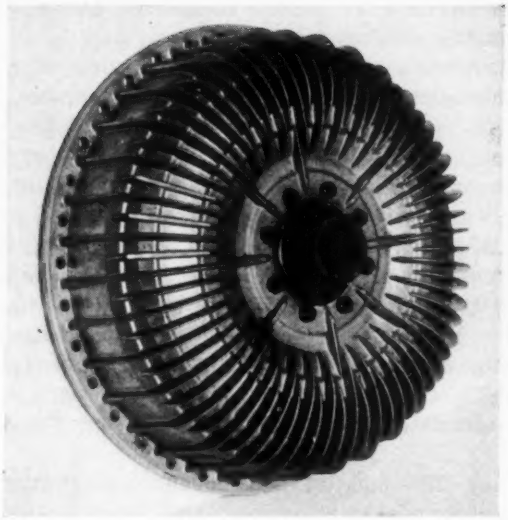
Choosing the process is important, since the casting method not only determines many features of the casting design but also affects choice of alloy.

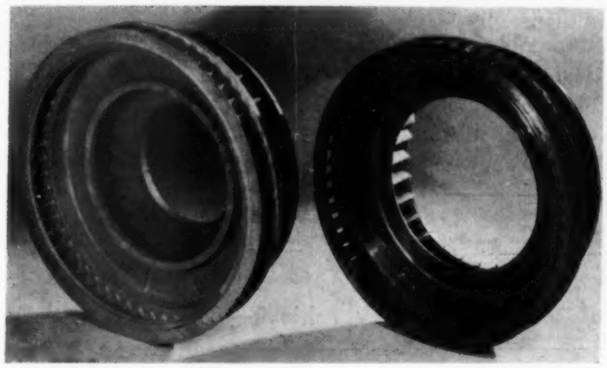
QUANTITIES: A major factor is the volume of parts required. Since pattern equipment for sand casting is much less expensive than dies for permanent-mold or pressure die casting, sand casting is indicated where small quantities are wanted. As larger quantities are called for, the point where it becomes economical to go to permanent-mold or die casting depends upon the size and complexity of the casting and other factors outlined later.

Die casting is primarily a mass production process and, as such, is widely used for instrument cases, instrument parts, toys, automotive parts and the like.

SIZE LIMITATIONS: This factor affects sand casting the least, with permanent-mold casting next. Die casting finds size restrictions most limiting, since cost of the die-casting machine and dies rises steeply with increased size of casting. New, large die-casting machines now raise some of the size limitations which formerly confined use of the process to comparatively small parts.

DIMENSIONAL TOLERANCES: Sand casting can be employed where relatively large dimensional tolerances are allowable. For closer tolerances, use of the metal dies of the permanent-mold or pres-





Aluminum castings are widely used in automotive hydraulic transmissions. Since intricate vane elements cannot be machined, these castings are made by plaster-mold or similar casting processes which produce smooth surfaces and precise dimensions

sure die-casting processes is advisable. Close tolerances may also be achieved in sand casting by employing highly developed practices utilizing special patterns, equipment and materials.

SURFACE FINISH: Metal dies usually produce a smoother surface than sand molds. In many cases, savings in machining or finishing may justify the added cost of the metal molds where otherwise the quantities involved would rule out the permanent-mold or die-casting processes.

SHAPE: Exceptionally intricate shapes can be cast in sand molds, using various types of core structures. This is the most versatile process as far as shape of the casting is concerned. However, permanent-mold and die casting are advancing rapidly in this respect.

MECHANICAL PROPERTIES: Strengths obtainable with permanent-mold and die-casting processes are generally higher than with sand casting because the metal molds produce more rapid solidification and hence improve soundness and microstructure.

DELIVERY TIME: Quicker delivery is usually enjoyed when sand castings are used because of elimination of the operations involved in making the metal dies required for permanent-mold and die-casting processes. Of course, this applies only to delivery of the initial order. Once the metal dies have been made, an order for most any given quantity can be turned out faster with them than with sand molds.

DESIGN FLEXIBILITY: Changes can be made in the design of a casting and new parts produced faster when sand cast than when permanent-mold or die cast. The latter processes involve work on the metal dies when a change in design of the cast part is necessary. Development work is usually done in sand casting prior to making molds for permanent-mold or die casting.

Types of Alloys: The common aluminum casting alloys, *Table* 2, contain one or more alloying elements to facilitate foundry operations, and to provide certain desired characteristics in the final castings themselves. The various alloy classifications can be divided into two general groups: (1) the binary alloys, aluminum and a single alloying element, and (2) the composite alloys employing two or more main alloying elements.

BINARY ALLOYS: This group includes the aluminum-copper, aluminum-silicon, and aluminum-magnesium alloys.

Binary aluminum-copper alloys are quite limited in number because the addition of nickel and/or magnesium to the aluminum-copper makes a much more useful material. Originally alloy 12 was in this classification, but now that a range of 1.1 to 2.5 per cent zinc is specified in alloy 12, it can no longer be considered a binary alloy.

Alloy 195 is essentially a binary alloy of copper and aluminum, although silicon and iron must be controlled by additions to improve casting characteristics. Finding limited usage in this category are alloys 112 and 212.

Binary aluminum-silicon alloys include the general-purpose sand, permanent-mold, and die-casting alloy 43 with nominal 5.25 per cent silicon,

and the die-casting alloys 13 and A13 with nominal 12 per cent silicon.

These alloys permit production of intricate castings with thick and thin sections; machine readily although not as easily as some other alloys; provide cast parts that are pressuretight; and offer excellent corrosion resistance. This latter factor has resulted in wide application in the textile industry and like fields where mild acids are encountered. They are also well suited to architectural, marine and household applications.

Alloys 43, 13 and A13 are nonheat-treatable alloys.

Binary aluminum-magnesium alloys include alloys 218, the various type alloys in the 214 series and 220 employing nominal 8, 4, and 10 per cent magnesium, respectively. These alloys feature an excellent combination of mechanical and chemical properties. They are especially resistant to corrosion and tarnish, being superior to practically all other common aluminum casting alloys in this respect. They even exceed the aluminum-silicon alloys in their resistance to marine atmospheres and mildly alkaline solutions.

The aluminum-magnesium alloys also offer excellent mechanical properties. For example, the highest mechanical properties of any of the aluminum sand-casting alloys are those of alloy 220: minimum tensile strength of 42,000 psi (ultimate), and 12 per cent elongation. It is not unusual to obtain 55,000 psi and 25 per cent. In fact, 46,000 psi tensile and 14 per cent elongation are considered *typical* values for alloy 220-T4.

This high strength is equaled only by the die-casting alloy A380 which has the same tensile strength (46,000 psi) but which has only 3 per cent elongation compared to 14 per cent for alloy 220.

Alloy 220 has its best mechanical properties, highest corrosion resistance, and greatest temperature stability when in the solution heat-treated condition (-T4). For this reason, alloy 220 should not be artificially aged.

The binary aluminum-magnesium alloys offer

Table 2—Aluminum Casting Alloy Compositions[1]

Alloy	Cu	Fe	Si	Mn	Mg	Zn	Ni	Ti	Sn	Cr	Others
12	6.0–8.0	1.2	1.0–4.0	0.5	0.07	1.1–2.5	0.3	0.2	..	..	0.5
13[2]	0.6	0.8	11.0–13.0	0.3	0.1	0.3	0.5	..	0.1	..	0.2
A13	0.1	0.6	11.5–12.5	0.05	0.03	0.05	0.05	..	0.05	..	0.1
43	0.1	0.6	4.5–6.0	0.1	0.05	0.1	..	0.2	..	..	0.15
85	3.5–4.5	1.0	4.5–5.5	0.5	0.1	0.9	0.5	..	0.3	..	0.5
108	3.5–4.5	0.8	2.5–3.5	0.3	0.03	0.2	..	0.2	..	..	0.3
A108	4.0–5.0	0.8	5.0–6.0	0.3	0.1	0.5	..	0.2	..	..	0.5
112	6.0–8.0	1.2	1.0	0.5	0.07	2.0	0.3	0.2	..	..	0.5
113	6.0–8.0	1.2	1.0–3.0	0.5	0.07	1.0–2.2	0.3	0.2	..	..	0.5
C113	6.0–8.0	1.2	3.0–4.0	0.5	0.07	2.5	0.5	0.2	..	..	0.5
122	9.2–10.8	1.3	1.0	0.5	0.15–0.35	0.5	0.3	0.2	..	..	0.3
A132	0.5–1.5	1.0	11.0–13.0	0.1	0.9–1.3	0.1	2.0–3.0	0.2	..	..	0.15
D132	2.0–4.0	1.0	8.5–10.5	0.5	0.5–1.5	0.5	0.5–1.5	0.2	..	..	0.5
138	9.5–10.5	1.2	3.5–4.5	0.5	0.15–0.35	0.5	0.5	0.2	..	..	0.5
142	3.5–4.5	0.6	0.6	0.3	1.3–1.8	0.1	1.7–2.3	0.2	..	..	0.15
A142	3.7–4.5	0.6	0.6	0.1	1.3–1.7	0.1	1.8–2.3	0.07–0.18	..	0.15–0.25	0.15
195	4.0–5.0	0.8	0.7–1.2	0.3	0.03	0.1	..	0.2	..	..	0.15
B195	4.0–5.0	0.8	2.0–3.0	0.3	0.03	0.3	..	0.2	..	..	0.15
212	7.0–8.5	1.2	1.0–1.5	0.3	0.05	0.2	..	0.2	..	..	0.3
214	0.1	0.3	0.3	0.3	3.7–4.5	0.1	..	0.2	..	..	0.15
A214	0.1	0.3	0.3	0.3	3.5–4.5	1.4–2.2	..	0.2	..	..	0.15
B214	0.1[4]	0.3[4]	1.4–2.2	0.3[4]	3.5–4.5	0.1	..	0.2	..	0.2	0.15
C214	0.1	0.8	0.3	0.4–0.6	3.5–4.5	0.1	..	..	..	..	0.15
F214	0.1	0.3	0.3–0.7	0.3	3.5–4.5	0.1	..	0.2	..	..	0.15
L214	0.1	0.6–0.9	0.5–1.0	0.4–0.6	2.5–4.0	0.1	0.1	..	0.1	..	0.15
218	0.2	0.8	0.3	0.3	7.5–8.5	0.1	0.1	..	0.1	..	0.15
220	0.2	0.2	0.2	0.1	9.6–10.6	0.1	..	0.2	..	..	0.15
319[2]	3.0–4.5	1.0	5.5–7.0	0.8	0.5	1.0	0.5	0.2	..	..	0.5
A319	3.0–4.5	0.8	5.5–7.0	0.5	0.1	0.8	0.2	0.2	..	..	0.5
333	3.0–4.5	1.0	8.0–10.0	0.8	0.6	1.0	0.5	0.2	..	..	0.5
355	1.0–1.5	0.4[3]	4.5–5.5	0.3[3]	0.4–0.6	0.2	..	0.2	..	..	0.15
356	0.2	0.4	6.5–7.5	0.1	0.2–0.4	0.1	..	0.2	..	..	0.15
360[2]	0.6	0.8	9.0–10.0	0.3	0.4–0.6	0.5	0.5	..	0.1	..	0.2
A360	0.1	0.5	9.0–10.0	0.1	0.4–0.6	0.1	..	..	..	..	0.15
380[2]	3.0–4.0	1.0	7.5–9.5	0.5	0.1	0.9	0.5	..	0.3	..	0.5
A380	3.0–4.0	0.6	7.5–9.5	0.1	0.05	0.1	0.1	..	..	..	0.15
382	0.1	0.4	3.0–4.0	0.1	1.7–2.5	..	..	0.2	..	0.2	0.15
384	3.0–4.5	1.0	11.5–13.0	0.6	0.1	1.2	0.6	..	0.3	..	0.5
A612	0.35–0.65	0.4	0.15	0.05	0.60–0.80	6.0–7.0	..	0.2	..	..	0.15
C612	0.35–0.65	1.3	0.3	0.05	0.25–0.45	6.0–7.0	..	0.2	..	..	0.15
750	0.7–1.3	0.5	0.7	0.1	..	..	0.7–1.3	0.2	5.5–7.0	..	0.3

[1]Values are in per cent maximum unless shown as a range; aluminum remainder.

[2]Alloys A13, A319, A360 and A380 have the same compositions as alloys 13, 319, 360 and 380, respectively, but impurities, notably iron and manganese, are controlled to closer limits.

[3]If iron content exceeds 0.4 per cent, manganese content is approximately one-half the iron content.

[4]If copper content plus iron content exceeds 0.5 per cent, manganese content is at least 0.3 per cent.

good machining characteristics. These alloys cannot be welded as easily as some other aluminum casting alloys; however, 4 per cent magnesium alloys weld easier than many of the heat-treatable copper alloys.

While alloy 220 is heat treatable, alloys 214 and 218 are *not* heat treatable.

Composite Alloys: Involving two or more principal alloying elements in addition to aluminum, these alloys form some of the most useful of all the aluminum casting alloys. It should be noted that any alloying element whose percentage value is controlled within a specified range is considered here as being a principal alloying element. This is the basis for the following alloy classifications.

Aluminum-copper-silicon alloys can be divided roughly into three groups according to copper content. Those with nominal 3.75 per cent copper include 85, 108, 319, A319, 333, 380, A380 and 384. Alloys with 4.5 per cent copper include A108 and B195. Those with 6 to 8 per cent copper include 12 and C113.

These alloys have almost completely replaced the original binary alloy of aluminum and copper, with the exception of 195 alloy. As a general statement, it can be said that these alloys contain cop-

Table 3a—Typical Properties and Applications: Sand Casting Alloys

Alloy	Tensile Strength (1000 psi)	Yield Strength (1000 psi)	Elongation (per cent)	Normally Heat Treated?	Strength at Elevated Temperatures	Resistance to Corrosion	Applications
12	23	14	2.0	No	Good	Good	General-purpose castings requiring moderate strength. Crankcases, oil pans, gear covers, transmission housings.
43	19	8	8.0	No	Fair	V. Good	Architectural and ornamental parts, pipe fittings, cooking utensils, food-handling equipment, marine fittings.
108	21	14	2.5	No	Good	Fair	Manifolds, valve bodies and other similar castings requiring pressure tightness.
112	24	15	1.5	No	Good	Fair	Miscellaneous, general-purpose castings. Transmission housings, cover plates, manifolds.
113	24	15	1.5	No	Good	Poor	General-purpose castings requiring pressure tightness. A modification of 112 providing better pressure tightness.
122[3]	41	40	[2]	Yes	Excell.	Fair	Retains strength at elevated temperatures. Air-cooled cylinder heads. Solution heat-treated and aged castings used for bearings, bearing caps, bushings, tappet guides.
143[3]	30	23	2.0	Yes	Excell.	Fair	Good strength at elevated temperatures. Air-cooled cylinder heads, diesel-engine pistons.
195[1]	36	24	5.0	Yes	Good	Good	Commonly used for parts requiring strength and ruggedness. Flywheel housings, rear-axle housings, bus wheels, spring hangers, aircraft wheels, crankcases.
212	23	14	2.0	No	Good	Poor	Improved foundry characteristics over 112 alloy and less hot short. Generally used interchangeably with 112 for applications such as housings, cover plates, etc.
214	25	12	9.0	No	V. Good	Excell.	Excellent resistance to corrosion and tarnishing and good combination of mechanical properties. Dairy and food-handling equipment, cooking utensils, fittings for chemical and sewage use.
B214	20	13	2.0	No	Good	Excell.	Improved foundry characteristics over 214 alloy but reduced mechanical properties. Excellent resistance to corrosion.
F214	21	12	3.0	No	Good	Excell.	Modification of 214 providing improved foundry characteristics with more uniform appearance after Alumilite treatment. Ornamental hardware and architectural castings requiring Alumiliting.
220[4]	46	25	14.0	Yes	[5]	Excell.	Best combination of high mechanical properties and corrosion resistance of any of sand-casting alloys. Not recommended for use at operating temperatures exceeding 250 F.
319	27	18	2.0	Yes	Good	Good	Excellent casting characteristics with good mechanical properties. Piano plates and frames, gasoline and oil tanks, oil pans, internal combustion and diesel engine crankcases.
355[1]	35	25	3.0	Yes	V. Good	Good	General-purpose castings requiring fairly high strength and corrosion resistance.
356[1]	33	24	3.5	Yes	Good	V. Good	Similar to 355 but having better pressure tightness and corrosion resistance.

[1]Mechanical properties for T6 condition. [2]Less than 1.0 per cent. [3]Mechanical properties for T7 condition. [4]Mechanical properties for T4 condition. [5]Not recommended for applications in which operating temperature exceeds 250 F.

per in various specified ranges from 3 to 8.5 per cent with controlled quantities of silicon and various other elements.

Alloys in this classification are characterized by improved machining qualities. Those with high silicon content provide the high fluidity required for castings with moderately thin sections.

Alloys B195, 319, A319 and 333 are heat treatable and will provide various desirable combinations of strength and ductility according to the heat-treating cycle employed. Other copper-silicon alloys (12, 85, 108, A108, C113, 212, 380, A380 and 384) respond to heat treatment, but are not normally considered heat-treatable alloys and are usually used in the as-cast condition.

Alloys in this classification considered as sand casting alloys are 12, 108, and 319. Those regarded as suitable for permanent- mold casting are A108, C113, B195, 319 and 333. Those suitable for die casting are 85, 380, A380 and 384.

Aluminum-silicon-magnesium alloys include 355, 356, 360, A360 and 382. These also can be grouped according to magnesium content as: 355, 356, 360 and A360 with roughly 0.2 to 0.6 per cent magnesium; and 382 with 1.7 to 2.5 per cent magnesium. Silicon content is specified for various ranges from 5.0 for 355 to 10.0 for 360 and A360.

Alloys in this classification possess the highly desirable features of castability, pressure tightness, strength, and corrosion resistance.

Alloys 360, A360 and 382 are usually not heat treated when die cast. When cast by other methods they may be heat treated if desired, since they do respond to heat treatment.

Various combinations of improved mechanical properties can be obtained by suitable heat treat-

Table 3b—Typical Properties and Applications: Permanent-Mold Casting Alloys

Alloy	Tensile Strength (1000 psi)	Yield Strength (1000 psi)	Elongation (per cent)	Normally Heat Treated?	Strength at Elevated Temperatures	Resistance to Corrosion	Applications
43	23	9	10.0	No	Fair	V. Good	Excellent castability, pressure tightness, corrosion resistance and weldability. General-purpose castings of thin sections. Carburetor bodies, cooking utensils, refrigerator fittings.
A-108	28	16	2.0	No	Good	Fair	Used for castings requiring pressure tightness and moderate strength. Ornamental grilles, reflectors and general-purpose castings.
113	28	19	2.0	No	Good	Poor	Washing - machine agitators, hydraulic brake pistons, diesel cylinder head covers, general-purpose pressure-tight castings.
C-113	30	24	1.0	No	Good	Poor	Washing-machine agitators, automotive cylinder heads.
122[1]	48	36	[2]	Yes	Excell.	Poor	Retains strength at elevated temperatures. Meter parts, bushings, bearing caps, automotive pistons.
A-132[1]	47	43	0.5	Yes	V. Good	Good	Good high-temperature properties, low coefficient of thermal expansion. Pulleys and sheaves, automotive and diesel pistons.
D-132[3]	36	28	1.0	Yes	V. Good	Fair	Similar to A-132 but with improved casting characteristics.
138	30	24	1.5	No	V. Good	Poor	High hardness in as-cast condition. Good machinability. Sole plates for electric hand irons.
A-142[1]	47	42	0.5	Yes	Excell.	Fair	Good strength at elevated temperatures. Diesel and aircraft pistons, aircraft generator housings, air-cooled cylinder heads.
B-195[1]	40	26	5.0	Yes	V. Good	Fair	Aircraft fittings, aircraft gun-control parts, aircraft wheels, railroad-car seat frames, fuel-pump bodies, aircraft gear housings.
A-214	27	16	7.0	No	V. Good	V. Good	Good resistance to corrosion and tarnishing. Responds well to Alumilite process. Cooking utensils, architectural fittings.
B-214	..	..	..	No	Good	Excell.	Improved foundry characteristics over A-214. Cooking utensils and pipe fittings for marine as well as general use.
319	34	19	2.5	Yes	Good	Good	Excellent casting characteristics, with good mechanical properties. Typewriter frames, engine parts, water-cooled cylinder heads.
333[1]	42	30	1.5	Yes	V. Good	V. Good	Mechanical properties and relatively low thermal expansion suitable for high temperature uses. Pistons, sole plates.
355[1]	43	27	4.0	Yes	V. Good	Good	General-purpose alloy with high strength and good pressure tightness. Aircraft parts, timing gears, fuel-pump bodies.
356[1]	40	27	5.0	Yes	Good	V. Good	General-purpose alloy similar to 355 but with slightly better pressure-tightness and corrosion resistance. Machine-tool parts, aircraft pump parts, band wheels.
382	..	..	..	No	Fair	V. Good	Cooking utensils, pipe fittings and architectural parts.

[1]Mechanical properties for T6 condition. [2]Less than 1.0 per cent. [3]Mechanical properties for T5 condition.

ment of alloys 355 and 356, the other heat-treatable alloys in this classification.

Aluminum-silicon-magnesium alloys suitable for sand casting are 355 and 356; for permanent- mold casting, alloys 355, 356 and 382; for die casting, alloys 360 and A360.

Aluminum-silicon-nickel-copper-magnesium alloys A132, D132 and Z132 provide a unique combination of properties that make these alloys particularly suited for pistons for internal combustion engines. Low thermal expansion and excellent dimensional stability make these alloys outstanding for this application. The alloys retain their strength well at elevated temperatures and possess good resistance to wear. Of course, the nickel content is primarily responsible for the good high-temperature characteristics of these alloys, which are so well suited to this type of work that they are sometimes referred to as "piston" alloys.

All the alloys in this classification respond to heat treatment and are usually employed in the heat-treated condition. Too, all these alloys are primarily for permanent-mold casting.

Aluminum-copper-nickel-magnesium alloys are another class widely used for their good high-temperature characteristics. Alloy 142 ("Y" alloy) and A142 are in this group. In addition to retaining strength well at elevated temperatures, castings of these alloys also possess good resistance to wear.

These alloys are similar in characteristics to the aluminum-silicon-nickel-copper-magnesium alloys mentioned in the previous section, and in addition have improved machinability, but slightly higher thermal expansion.

Alloy 142 and A142 provide high mechanical properties and dimensional stability upon suitable heat treatment. They can be cast either as sand or permanent-mold castings and are used predominantly in pistons and cylinder heads.

Aluminum-zinc-magnesium alloys such as A612 and C612, have several notable characteristics. First is the substantial increase in tensile and yield strengths with loss of ductility that occurs on natural aging at room temperature for approximately 30 days. This aging continues to progress for almost a year. The net effect is to provide these alloys with tensile strengths comparable to heat-treated alloys without the necessity of heat treating them.

These alloys have the unique ability to with-

Table 3c—Typical Properties and Applications: Die-Casting Alloys

Alloy	Tensile Strength (1000 psi)	Yield Strength (1000 psi)	Elongation (per cent)	Strength at Elevated Temperatures	Resistance to Corrosion	Applications
13	39	21	2.0	Good	Good	Excellent casting characteristics and very good corrosion resistance. Good mechanical properties. Typewriter frames, outboard-motor pistons, dental equipment. A general-purpose alloy for large, intricate parts with thin sections.
A13	..	..	..	Good	Good	Similar to 13 alloy with impurities more closely controlled. Same general applications as 13, but which require higher elongation than provided by 13 alloy.
43	30	16	9.0	Poor	Good	Excellent castability and pressure tightness, good weldability. General-purpose medium strength castings.
85	40	24	5.0	Good	Poor	Good combination of strength and ductility. Casts well in thick sections. Brackets, frames and levers with thick sections.
C214	41	..	8.0	V. Good	V. Good	Hardware, support brackets. Good corrosion resistance.
218	45	27	8.0	Fair	Excell.	Excellent resistance to corrosion and tarnish as well as excellent strength and ductility. Does not cast as well in intricate parts as 13 alloy. Responds well to Alumiliting.
360	44	27	3.0	Excell.	V. Good	Excellent casting characteristics. Good mechanical properties and corrosion resistance. Cover plates, instrument cases, general-purpose castings.
A360	41	23	5.0	Good	V. Good	Impurities controlled to lower limits than in 360 alloy. Has somewhat better elongation than 360.
380	45	26	2.0	V. Good	Fair	Good casting characteristics and mechanical properties. General-purpose castings.
A380	46	25	3.0	V. Good	Fair	Impurities controlled to closer limits than in 380 alloy.
384	46	27	1.0	Good	Good	Pistons.

stand heating to brazing temperature, yet will regain their original strength upon aging at room temperature for a few days. They are not considered desirable for intricate castings.

Selecting the Alloy: After the method of production for the part is decided—that is, sand, permanent-mold or die casting—the next step is to determine the necessary properties and fabrication characteristics. When choosing an alloy, the following factors must be taken into consideration:

MECHANICAL PROPERTY requirements, *Tables 3a, b* and *c*, will usually determine whether or not the alloy must be heat treatable. High strength requirements necessitate the use of a heat-treatable alloy. In certain applications, special requirements, such as extreme hardness, high impact resistance or dimensional stability, will determine which alloy is to be employed.

Physical properties must also be considered in special applications where high electrical or thermal conductivity, good corrosion resistance,

Table 4a—Casting Characteristics: Sand Casting Alloys

Alloy	Hot Cracking Resistance	Pressure Tightness	Fluidity	Solidification Shrinkage Tendency
12	Good	Good	V. Good	V. Good
43	Excell.	Excell.	Excell.	Excell.
108	V. Good	V. Good	V. Good	V. Good
112	Good	Fair	Good	Good
113	Good	Good	V. Good	Good
122	Good	Good	Good	Good
142	Fair	Good	Good	Fair
195	Fair	Fair	Good	Good
212	V. Good	Good	V. Good	Good
214	Fair	Poor	Poor	Poor
B214	Good	Fair	Good	Fair
F214	Good	Fair	Good	Fair
220	V. Good	Poor	Fair	Poor
319	V. Good	V. Good	V. Good	V. Good
355	Excell.	Excell.	Excell.	Excell.
356	Excell.	Excell.	Excell.	Excell.

Table 4b—Casting Characteristics: Permanent-Mold Casting Alloys

Alloy	Hot Cracking Resistance	Pressure Tightness	Fluidity	Solidification Shrinkage Tendency
43	Excell.	Excell.	Excell.	V. Good
A108	V. Good	V. Good	V.Good	V. Good
113	Good	Good	V. Good	Good
C113	Good	Good	V. Good	Good
122	Fair	Fair	Good	Fair
A132	Excell.	V. Good	Excell.	Good
D132	V. Good	V. Good	V. Good	Good
138	V. Good	Good	V. Good	Good
A142	Fair	Fair	Good	Fair
B195	Fair	Good	Good	Good
A214	Fair	Fair	Fair	Fair
B214	Good	Fair	Fair	Fair
319	V. Good	V. Good	V. Good	Good
333	V. Good	V. Good	Excell.	Good
355	Excell.	Excell.	V.Good	V. Good
356	Excell.	Excell.	V. Good	Excell.
382	V. Good	V. Good	Fair	V. Good

Table 4c—Casting Characteristics: Die Casting Alloys

Alloy	Hot Cracking Resistance	Pressure Tightness	Fluidity
13	Excell.	V. Good	Excell.
A13	Excell.	V. Good	Excell.
43	V.Good	Good	Good
85	Fair	Good	Poor
C214	Fair	Poor	Poor
218	Poor	Poor	Fair
360	Excell.	Excell.	Excell.
A360	Excell.	Excell.	Excell.
380	V. Good	V. Good	V. Good
A380	V.Good	V. Good	V. Good
384	V. Good	V. Good	V. Good

Table 5a—Fabrication Characteristics: Sand Casting Alloys

Alloy	Machining	Gas Welding	Arc Welding	Resistance Spot & Seam Welding
12	V. Good	Fair	Fair	Fair
43	Poor	Excell.	Excell.	Excell.
108	Good	V. Good	Fair	V. Good
112	V. Good	V. Good	V. Good	V. Good
113	V. Good	V. Good	Excell.	V. Good
122	Excell.	Good	V. Good	V. Good
142	V. Good	Good	V. Good	V. Good
195	V. Good	Good	V. Good	V. Good
212	V. Good	V. Good	V. Good	V. Good
214	Excell.	V. Good	Excell.	V. Good
B214	V. Good	V. Good	Excell.	V. Good
F214	V. Good	V. Good	Excell.	V. Good
220	Excell.	Fair	Good	V. Good
319	Good	V. Good	Excell.	V. Good
355	Good	Excell.	Excell.	Excell.
356	Fair	Excell.	Excell.	Excell.

Table 5b—Fabrication Characteristics: Permanent-Mold Casting Alloys

Alloy	Machining	Gas Welding	Arc Welding	Resistance Spot & Seam Welding
43	Poor	Excell.	Excell.	Excell.
A-108	Good	Excell.	Excell.	V. Good
113	V. Good	V. Good	Excell.	V. Good
C-113	V. Good	V. Good	Excell.	V. Good
122	Excell.	Fair	Good	V. Good
A-132	Fair	Fair	Good	Good
D-132	Good	Fair	Fair	Fair
138	V. Good	Fair	Good	Good
A-142	V. Good	Good	V. Good	V. Good
B-195	Good	Good	V. Good	V. Good
A-214	V. Good	V. Good	Excell.	V. Good
B-214	Excell.	V. Good	Excell.	V. Good
319	Good	Fair	Fair	Fair
333	Good	Fair	Fair	Fair
355	Good	Excell.	Excell.	Excell.
356	Good	Excell.	Excell.	Excell.
382	Excell.	Good	Good	Good

Table 5c—Fabrication Characteristics: Die Casting Alloys*

Alloy	Machining	Alloy	Machining
13	Fair	360	Good
A13	Fair	A360	Good
43	Poor	380	Good
85	V. Good	A380	Good
C214	V. Good	384	Fair
218	Excellent		

*Welding rating "fair" for gas, arc, and resistance spot and seam welding for all alloys.

low thermal expansion or certain other properties are needed.

STRENGTH AT ELEVATED TEMPERATURES rating, *Table* 3, is based on tensile and yield strength at temperatures up to 600 F, after prolonged heating at testing temperature.

RESISTANCE TO CORROSION, *Table* 3, is based on the alloy resistance in standard type salt-spray tests and previous experience.

Table 6a—Finishing Characteristics: Sand Casting Alloys

Alloy	Polishing	Electroplating	Anodizing (appearance)	Chemical Oxide Coating Protection
12	V. Good	V. Good	Good	Fair
43	Poor	V. Good	Poor	V. Good
108	Good	V. Good	Good	Good
112	V. Good	V. Good	Good	Fair
113	V. Good	V. Good	Good	Fair
122	V. Good	Excell.	Good	Fair
142	V. Good	Excell.	Good	Fair
195	V. Good	Excell.	V. Good	Good
212	V. Good	V. Good	Good	Fair
214	Excell.	Poor	Excell.	Excell.
B214	V. Good	Fair	V. Good	Excell.
F214	V. Good	Fair	Excell.	Excell.
220	Excell.	Fair	Excell.	Excell.
319	Fair	V. Good	Fair	Good
355	Good	Excell.	Fair	V. Good
356	Poor	V. Good	Fair	V. Good

Table 6b—Finishing Characteristics: Permanent-Mold Casting Alloys

Alloy	Polishing	Electroplating	Anodizing (appearance)	Chemical Oxide Coating Protection
43	Fair	V. Good	Fair	V. Good
A-108	Good	V. Good	Good	Good
113	V. Good	V. Good	Good	Fair
C-113	V. Good	V. Good	Good	Fair
122	V. Good	Excell.	Good	Fair
A-132	Poor	Fair	Poor	V. Good
D-132	Good	Fair	Poor	Poor
138	V. Good	Poor	Fair	Poor
A-142	V. Good	Excell.	V. Good	Good
B-195	V. Good	Excell.	Good	V. Good
A-214	Excell.	Poor	Excell.	Excell.
B-214	Excell.	Poor	V. Good	Excell.
319	Good	V. Good	Fair	Good
333	Good	V. Good	Fair	Good
355	Good	V. Good	Fair	V. Good
356	Good	Excell.	Fair	V. Good
382	Fair	Good	Good	V. Good

Table 6c—Finishing Characteristics: Die Casting Alloys

Alloy	Polishing	Electroplating	Anodizing (appearance)	Chemical Oxide Coating Protection
13	Poor	Good	Poor	Good
A13	Poor	Good	Poor	Good
43	Fair	V. Good	Fair	Good
85	V. Good	Fair	V. Good	Poor
C214	Excell.	Fair	V. Good	Excell.
218	Excell.	Poor	Excell.	Excell.
360	Good	Excell.	Good	Good
A360	Good	Excell.	Good	Good
380	Good	Excell.	Good	Poor
A380	Good	Excell.	Good	Poor
384	Poor	Poor	Poor	Good

CASTING CHARACTERISTICS, *Tables* 4*a*, *b* and *c*, are especially important if a large or intricate casting is involved. Size and shape of the part to be cast determine the required foundry characteristics. For instance, if the casting has thin sections, an alloy with good fluidity must be selected. Moreover, for castings of intricate shape, together with thin sections, an alloy having both good fluidity and high resistance to hot cracking must be used. In many cases, it is impossible to find an alloy with all the particular requirements for a certain application. As a result, final selection of the alloy will be a compromise between the properties required and those actually obtainable.

RESISTANCE TO HOT CRACKING indicates the relative ability of the alloy to withstand contraction stresses while cooling through the hot-short temperature range. It is especially important when selecting a permanent-mold alloy for certain types of castings. For example, consider a part having the shape of a ring. If this part is to be cast in a permanent mold, the alloy used must have a high resistance to hot cracking in order to withstand contraction stresses which are set up as the casting solidifies and contracts around the mold core.

PRESSURE TIGHTNESS refers to the alloy casting being airtight or watertight under pressure. Proper alloy selection and good foundry practice are necessary to obtain this goal.

FLUIDITY, the ability of the liquid alloy to flow readily in the mold and fill thin sections at normal pouring temperature, is especially important when considering intricately shaped castings having thin sections.

SOLIDIFICATION SHRINKAGE refers to the tendency of the alloy to decrease in volume when freezing. This rating gives an indication of the amount of compensating feed metal required in the form of risers.

MACHINABILITY rating, *Tables* 5*a*, *b* and *c*, is based on ease of cutting, chip characteristics, quality of finish and tool life. For the heat-treatable alloys, the ratings are based on the "-T6" temper. Other tempers, particularly the annealed ("O") temper, may have a lower rating.

POLISHING rating, *Tables* 6*a*, *b* and *c*, is based on the ease and speed of polishing and quality of finish provided by typical polishing procedure.

ELECTROPLATING characteristics, *Table* 6, are based on the ability of a casting to take and hold an electroplate applied by present standard methods.

ANODIZING characteristics are rated on lightness of color, brightness and uniformity of a clear anodized coating applied in a sulphuric acid electrolyte.

CHEMICAL OXIDE COATING value as a protection is rated on the combined resistance of coating and base alloy to corrosion.

Production Characteristics

Magnesium Alloys

Castability • Formability
Machinability • Weldability
Finishing characteristics

By Paul L. Filter
Dow Chemical Co.
Midland, Mich.

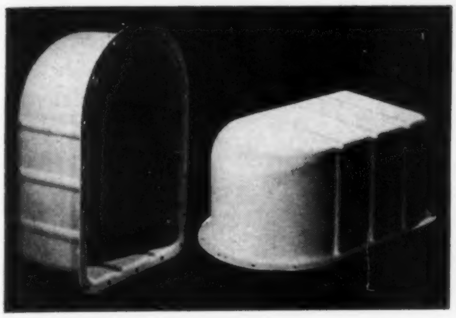
MAGNESIUM is only two-thirds the weight of aluminum and one-fourth the weight of steel. This light weight, combined with good strength properties, has made the metal useful for aircraft and airborne structures, materials-handling equipment, portable tools and various other types of equipment. But other characteristics of the metal have played increasingly important roles in the extended use of magnesium. These characteristics include high energy absorption, damping capacity and fatigue strength. One of the factors that has increased use of magnesium is the ability of the metal to be worked by all common means known to metalworking.

One of the factors influencing workability is the crystalline structure of magnesium. The usual structural metals, iron, steel and aluminum, have a cubic crystalline structure, while magnesium's crystalline structure is hexagonal. This hexagonal structure imposes some limitations on the amount

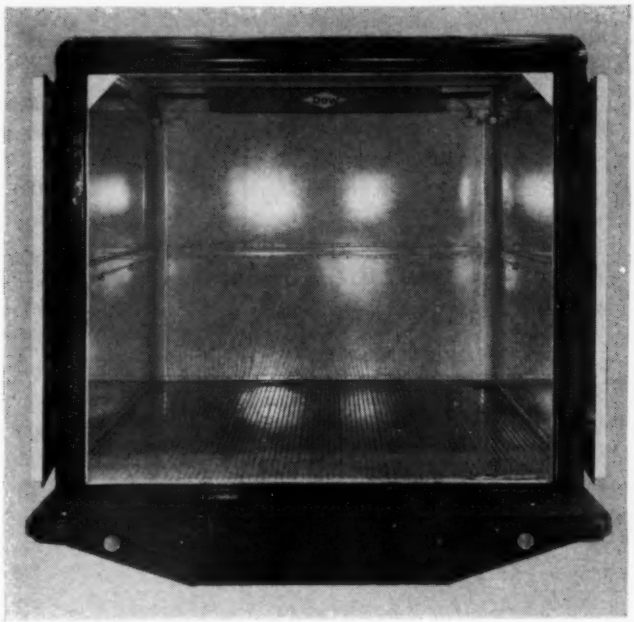
Table 1—Service Characteristics of Typical Magnesium Alloys

Alloy (ASTM)	Tensile Strength* (1000 psi)	Yield Strength*† (1000 psi)	Elongation* (% in 2 in.)	Hardness* (bhn)	Elevated Temperatures — Short-Time (<350F)	Elevated Temperatures — Short-Time (>350F)	Elevated Temperatures — Long-Time (1000-hr, 400F)	Creep	Toughness	Corrosion Resistance — Salt	Corrosion Resistance — Stress
Sand and permanent-mold casting alloys											
AZ92A	24–40	14–23	2–10	63–84	A	D	B	B	B	B	..
AM100A	22–40	12–22	1–10	52–69	B	D	..	B	C	D	..
AZ63A	29–40	14–19	5–12	50–73	B	D	B	B	A	B	..
AZ91C	24–40	14–19	2–11	52–73	B	D	..	B	A	C	..
EK30A	23	16	3	45	C	B	B	A	B	A	..
EK41A	23–25	16–18	1–2	50	B	A	..	A	B	A	..
EZ33A	23	16	2	50	C	B	A	A	B	A	..
Die-casting alloys											
AZ91A & B	33	22	3	60	B	D	..	B	C	C	..
Sheet alloys											
AZ31A	37–42	22–32	15–21	56–73	B	..	B	C	B+	A	C
AZ31B	.....	.....	.....	.....	B	..	..	C	B+	A	C
M1A	33–36	17–27	7–16	48–56	A	..	B	B	B	A–	A
Extrusion alloys											
AZ31B	36–38	24–29	15–16	46–49	C	..	..	B	A	A	C
AZ61A	41–45	28–33	14–16	50–60	B	..	..	B	B+	A	C
M1A	35–37	21–26	10–11	42–44	C	..	..	A	B–	A	A
AZ80A	49–55	36–40	7–11	60–82	A	..	..	C+	D	A	C–
ZK60A	49–53	38–44	11–14	75–82	A	..	..	D	B+	B	B+

*Average properties. †0.2% offset.

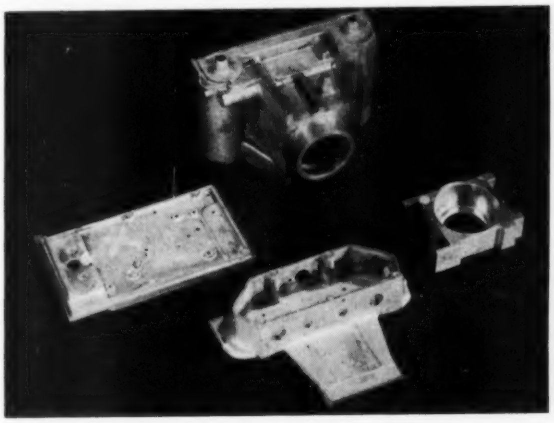


Above — Instrument housings deep-drawn from magnesium sheet. Parts are drawn in one operation without intermediate annealing



Right — Magnesium truck body with monocoque construction. Thick sheet is used for rigidity, eliminating internal framing

Die-cast magnesium parts used in the new Simmons Omega 120 camera



of deformation possible in the metal when worked cold. But when heated, the crystal structure makes many more slip planes available, thus making magnesium one of the easiest metals to hot-form and bend.

Because of the high strength-to-weight ratio of magnesium, simplified structures can be designed. Extruded sections can be designed to eliminate separate parts and fasteners. Simplified structures are made possible by utilizing thick plate walls to provide structural strength in place of internally braced designs. High joint efficiency obtainable with arc-welded magnesium is an important factor in the successful development of commercial structural applications.

Production characteristics of magnesium are classified in this article by product (i.e., sand castings, die castings, sheet, extrusions) and the specific characteristics are discussed under each of these headings. *Table* 1 lists mechanical properties and service characteristics of magnesium alloys. *Table* 2 contains information on the relative production characteristics of these alloys, and *Table* 3 lists chemical treatments for magnesium alloys.

Sand and Permanent-Mold Castings: Magnesium alloys for castings include AZ91C, AZ92A, AM80A, AM100A, AZ63A, EK30A-T6, EK41A, and EZ33A-T5, with the last three being the rare-earth-containing alloys for elevated-temperature use.

Castability of these alloys ranges from good to excellent. All of the alloys can be welded but must be stress-relieved after the welding operation.

As is common with magnesium alloys in any

Table 2—Production Characteristics of Typical Magnesium Alloys

Alloy (ASTM)	—Castability— Ease	Pressure Tightness	Hot Formability	—Weldability (Arc)— Ease	Weld Efficiency	Stress Relieve?
Sand and permanent-mold casting alloys						
AZ92A	A	B	..	B	..	Yes
AM100A	A	B	..	A	..	Yes
AZ63A	C	D	..	C	..	Yes
AZ91C	A	B	..	B	..	Yes
EK30A	B	A	..	A	..	Yes
EK41A	B	A	..	A	..	Yes
EZ33A	B	A	..	A	..	Yes
Die-casting alloys						
AZ91A & B	B	A	..	No	..	Yes
Sheet alloys						
AZ31A	..	..	A	C	A	Yes
AZ31B	..	..	A—	A	A	Yes
M1A	..	..	B	B+	C	No
Extrusion alloys						
AZ31B	..	..	A	A	A	Yes
AZ61A	..	..	A	B+	A	Yes
M1A	..	..	B	B+	C	No
AZ80A	..	..	B	B	B+	Yes
ZK60A	..	..	B	D	B	?

form, machinability is excellent. Highest possible machine-tool speeds can be used, and ordinary tool steels give excellent results.

Generally, sand castings in any of the alloys are given a chrome-pickle treatment (*Table* 3) for corrosion protection during storage and to provide a paint base. Painting usually consists of the application of a primer coat followed by an organic finish. For many commercial applications, such as in materials-handling equipment, it is common practice to use the castings unpainted or to use only a chemical treatment to provide a bright, attractive finish. Castings may be anodized for wear resistance and protection. Two new anodic finishes, the Dow No. 17 anodize and the HAE coating, have been developed. These finishes provide excellent wear and corrosion resistance and are suitable paint bases.

Die Castings: The two common magnesium die-casting alloys are AZ91A and AZ91B. The latter, designated as the commercial alloy, contains beryllium to control oxidation in the melting process.

Castability of both alloys is rated as good. The outstanding production advantage of magnesium for die casting lies in the fact that it will not alloy with iron and steel. This makes possible melting in cast-steel pots, stirring the melt with conventional air-driven, steel stirring equipment, and pumping of the molten metal with air-driven pumps through steel piping without danger of introducing dissolved iron into the melt. This characteristic has made possible the submerged-plunger, or "hot-chamber," die-casting machine for magnesium alloys.

Magnesium casting rates are high because of the low heat value which must be given up. This low heat value and nonalloying with iron tend to cause less wear on dies.

In addition to the usual finishing operations, magnesium die castings may be plated with any of the conventional electrodeposited metals. The plating operation differs from conventional plating only in that a zinc-immersion coat is applied to the magnesium before the usual plating operation begins.

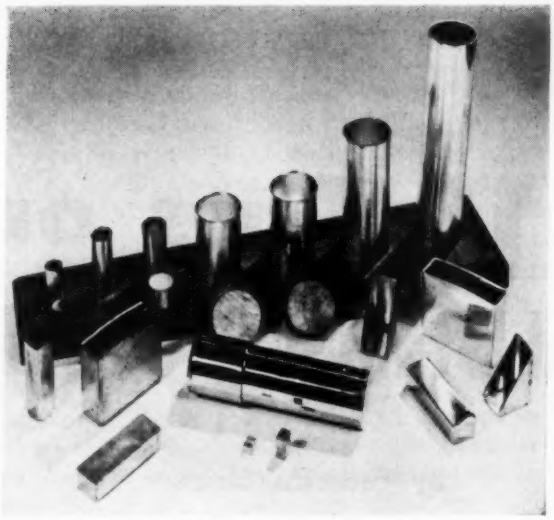
Sheet: As indicated previously, magnesium alloys in sheet form lend themselves well to hot-forming operations. The crystalline structure is such that, by preheating the sheet, more slip planes are available, making the sheet extremely formable. Parts can be formed in one draw in magnesium that would require several draw stages with several sets of dies in other metals. Blanking, drawing, spinning, roll forming and sharp bending operations are performed hot in magnesium. Bends of shallow radius may be performed cold.

Magnesium sheet may be joined by riveting, and gas, arc or spot welding. The recommended proc-

Fig. 3—Chemical Treatments for Magnesium Alloys

No.*	Treatment	For . . .	Appearance	No. Steps	Time (min)	Uses	Remarks
Chemical treatments							
1.	Chrome–pickle	All alloys	Matte gray to yellow red	5	6	General-purpose for shipment and storage protection. Good paint base.	Simple dip treatment, usually cheapest to apply. Etching action causes slight dimensional loss.
2.	Chrome–alum	AZ91A	Brown–black	6	10	Used only as black decorative finish for die castings.	Offers some improvement in paint adhesion.
3.	Dichromate	All aluminum-containing alloys and ZK60A	Brown	7	45	Provides best combination of paint base and protective qualities.	Does not materially affect dimensions.
4.	Alkaline–dichromate	Same as 3	Brown–black	9	45	Used for black finish on all forms. More protective on die castings than 2.	Protective and paint base qualities.
5.	Sealed chrome–pickle	All alloys	Similar to 1	7	35	Alternate for 3 when dimensional loss can be tolerated.	Improve protection over 1 because of boiling in dichromate solution.
6.	Bright finish	Wrought alloys	Silvery	5–7	10	Decorative finish.	Good "shelf life" appearance. Dimensions slightly affected.
7.	Bright finish	Cast alloys	Silvery	4–7	7	Decorative finish.	Similar to 6.
Electrochemical treatments							
8.	Galvanic anodize	All alloys	Black	7	30	Used on nonaluminum-containing alloys not treatable by 3 or 4.	....
9.	Caustic anodize	All alloys	Light shades of gray and tan	5–8	30	Specialty treatment combining decorative finish, abrasion resistance, protection.	Can be dyed. Neutralizing seal gives paint-base qualities equal to 3.
10.	A-c anodize	All alloys	Light gray to white	4–7	25	Most abrasion-resistant of chemical treatments. Can be painted when given neutralizing seal. Cannot be dyed.	Covers flow marks in die-cast surfaces. Should be waxed to prevent smudging.

*Arbitrary number for reference within table.



Typical shapes produced by impact extrusion of magnesium. With most press operations, magnesium must be worked hot

Chrome plating is one of several methods of finishing magnesium. Components shown are automotive die castings

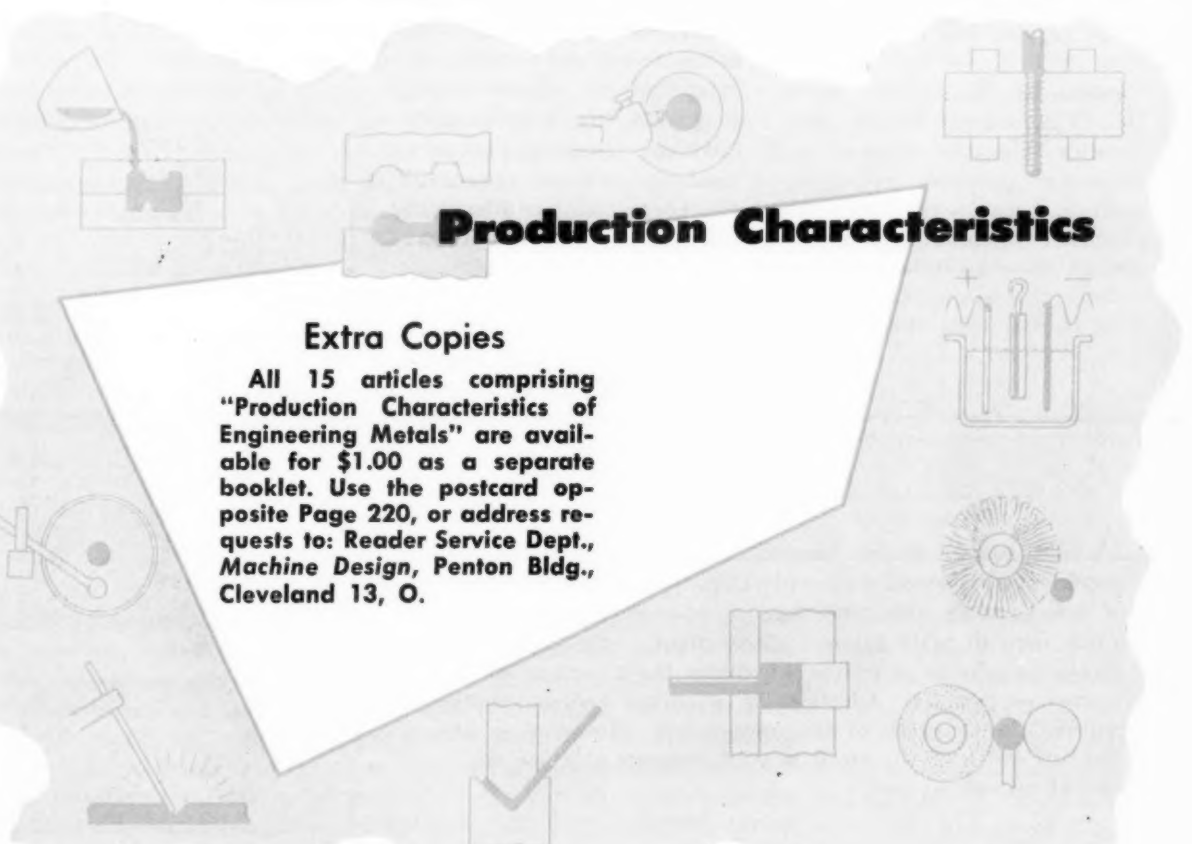
ess for welding is inert-gas-shielded arc welding utilizing argon or helium.

Extrusions: The extrusion process is particularly well adapted to magnesium because of good hot-flow characteristics of the metal. Virtually any profile may be produced as well as any of the standard tubes, angles and channels.

Magnesium extrusions are hot formed for best results, and have relatively the same forming characteristics as magnesium sheet. They may be joined by riveting or welding with inert-gas-shielded arc or spot-welding methods.

Finishing operations for extrusions are essentially the same as for other types of magnesium products.

General: Magnesium alloys may be impact-extruded in conventional equipment and require only a preheating step and application of the proper lubricant. Forgeability of magnesium alloys is generally rated as good.



PRODUCTION
Modern Practices in Manufacture
AND
DESIGN

18 Tips on Practical Stamping Design

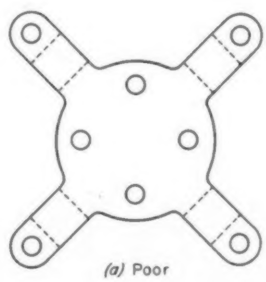
By Federico Strasser
Santiago, Chile

STAMPINGS must be designed in accordance with practical production techniques. The obvious statement — so often ignored — has several implications. Difficulties in building and heat treating the dies must be anticipated at the design stage. Stamping characteristics of the stock must be taken into account. Tight specifications that increase cost of production, such as tolerances more suited to precision machining than stamping, should be eliminated.

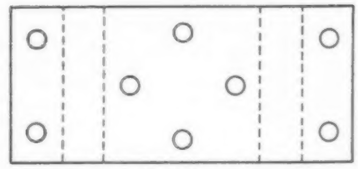
Economical and trouble-free production can be achieved through observance of a few simple rules when designing a stamped part. Here are 18 specific suggestions for lowering stamping costs.

1

Use simple blank contours. Cost of a blanking die is strongly affected by the contour, shape and intricacy of the blank. Blank contour should be as simple as possible. Simple blank contours require less time for construction of the dies. In addition, tool life—other conditions being equal—is notably influenced by the cutting shape. Sharp corners, narrow slots, etc., wear more rapidly and reduce tool life substantially. Usually, stock is wasted with intricate blanking contours. Whenever possible, use straight contours instead of curved profiles, because the latter make the corresponding dies more expensive to build, and often cause poor stock utilization. Although hole locations and stock allowances around holes are exactly the same, blank design *b* requires less expensive dies than *a*, and uses stock better.



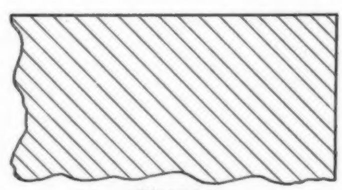
(a) Poor



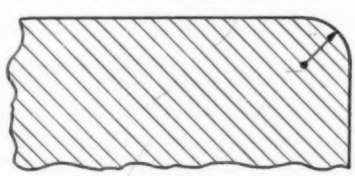
(b) Better

2

Avoid square blank corners. Square corners in die openings are difficult and costly to construct, create danger of breakage in hardening and in operation, and require much care in maintenance. Consequently, the corners of blanks should be a radius whenever the function of the workpiece permits. Additionally, a corner radius usually improves appearance of the components. However, where the full width of the stock is used, corners at stock edges should be left square.



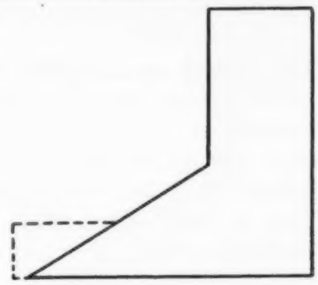
Wrong



Right

3

Eliminate sharp corners. Workpieces with pointed corners are even worse than those with plain square corners. Sharp corners shorten punch life considerably, and appearance of the stamping is also very unsatisfactory. If the part absolutely must be made with an acute angle, then it must be blanked on the dotted lines and the excess metal cut away in a second-operation trimming die. Second operations are expensive, and should be permitted only in exceptional cases.

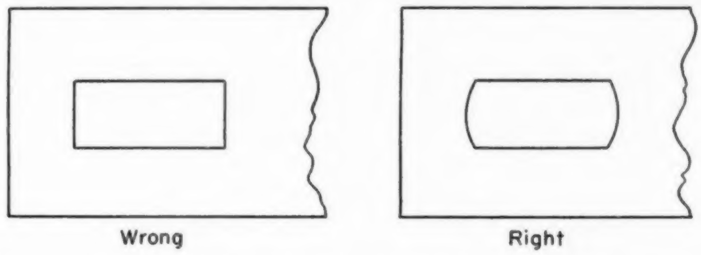


4

Use round holes if possible. Round holes or sections are always easier to machine on dies than any other shape or form. Both the punch and the corresponding opening in the die plate are made quickly and with great exactness, because all machining operations are effected with ordinary machine tools, without any need for tedious bench work.

5

Round ends of slots. If a hole must be elongated, then design the slot with rounded ends and not with straight ends. The former design is better and simpler and the tool is cheaper to make.

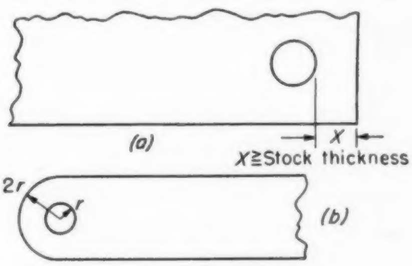


6

Standardize hole sizes. When several holes are to be punched in a part, try to make them identical in shape and size, to take advantage of the obvious economies.

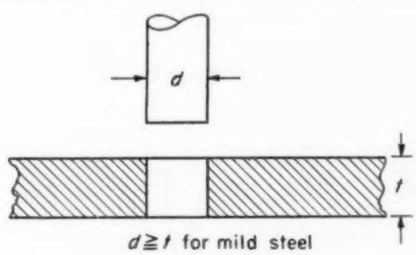
7

Locate holes away from edges. Pierced holes or slots should be located away from component edges to avoid deformation and distortion in the stamping. For best results, the hole edge should be at a distance from the blank edge corresponding at least to stock thickness, *a*. In addition, independent from stock thickness, around every hole there usually should be at least as much stock as the radius of the hole itself, *b*.



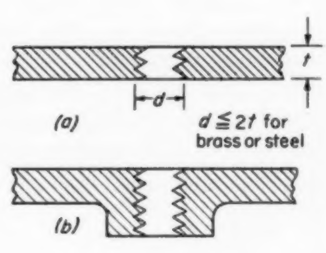
8

Watch small hole sizes. Referring to small holes in general, remember that there is a lower limit of hole size under which it is not convenient to pierce metals. The minimum size depends on construction of the tool, ultimate shearing strength of the stock, stock thickness, etc. For mild steel, the min'mum punchable hole diameter (round holes) coincides approximately with stock thickness.



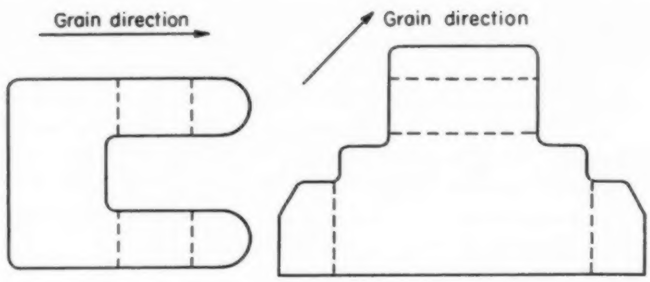
9

Check threaded hole strengths. Strength of threaded holes must be carefully checked. Actual practice shows that for steel or brass, stock thickness should be no less than half the thread diameter, *a*. For softer metals, such as zinc or aluminum, stock thickness must be even more—at least 2/3 of the thread diameter. If this condition cannot be satisfied, then it is not necessary to increase stock thickness (wasting material) or to employ a large number of small screws. Instead, use flanged or extruded holes, *b*. With this method, thread length will be approximately double the stock thickness, or even more.



10

Make bends across grain. Bends should be made across the stock grain direction (direction of rolling, or length for coil stock), and grain direction should be so specified. If bend lines must be perpendicular to each other, grain should be at a 45-degree angle.

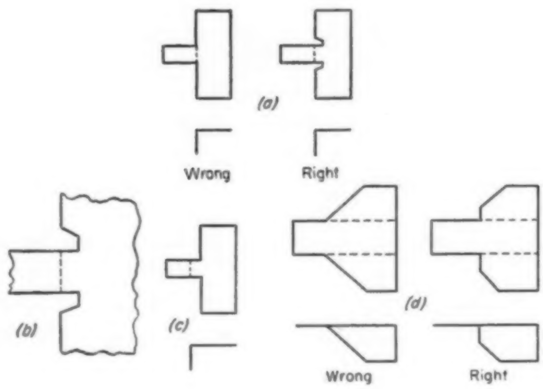


11

Use large bend radii. Designate the largest practical bending radius since this permits much greater allowance in material selection (ductility requirements are not so demanding) and will often assure a better bend.

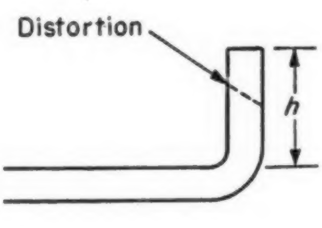
12

Place bend lines correctly. Sometimes the whole workpiece, in its full width, cannot be bent but only a small portion of it. To avoid tearing the metal, a slight notch must be made at the stressed points, *a*. Size and shape of the notch are immaterial; it is preferable to make them half-round or trapezoidal, *b*. However, the best method consists of locating the bending line outside of the larger part area, *c*. To avoid distortions and tearing of the metal, the part contour should meet at right angles with the bending line, *d*.



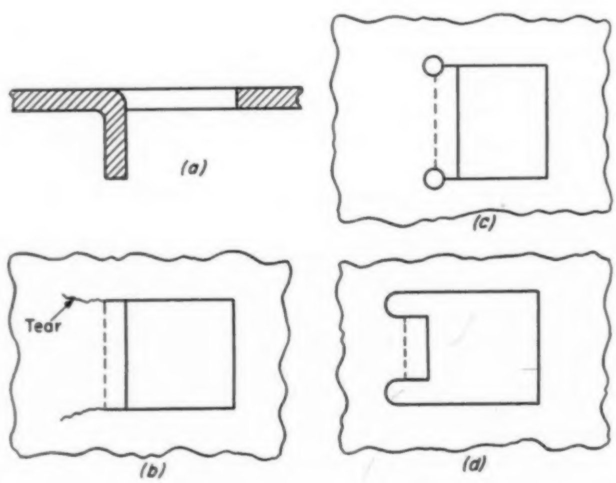
13

Allow adequate bent leg height. Right angle bent workpieces must have a minimum height to avoid distortion. Minimum *h* varies from 2 to 4 times stock thickness, depending on material thickness (heavier stock—less height), bend radius (greater radius—more height), material temper, etc. If less height than can be obtained directly is absolutely necessary, the workpiece legs must be bent somewhat longer and then trimmed or milled down to the required dimension.



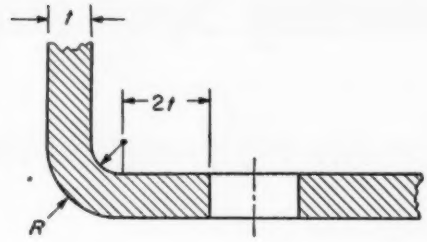
14

Relieve stresses at critical points. A frequently employed special forming operation is lancing or lug forming which consists of progressive shearing and forming of ears or lugs, *a*. The material is likely to tear at points of greatest stress, *b*. To avoid this trouble, stresses must be relieved in the critical points by small round holes, *c*, or rectangular notches, *d*.



15

Keep holes away from bend lines. If a hole is located too close to the bending zone, it is likely to be distorted. For safe conditions, the hole edge must be at least twice the stock thickness from the inside radius center. When it is imperative that the hole be nearer the bend line, either a supplementary relieving slot must be punched, the hole must be elongated, or it must be pierced after bending. All these solutions are unsatisfactory, requiring more expensive tools. The last one also increases labor costs considerably.

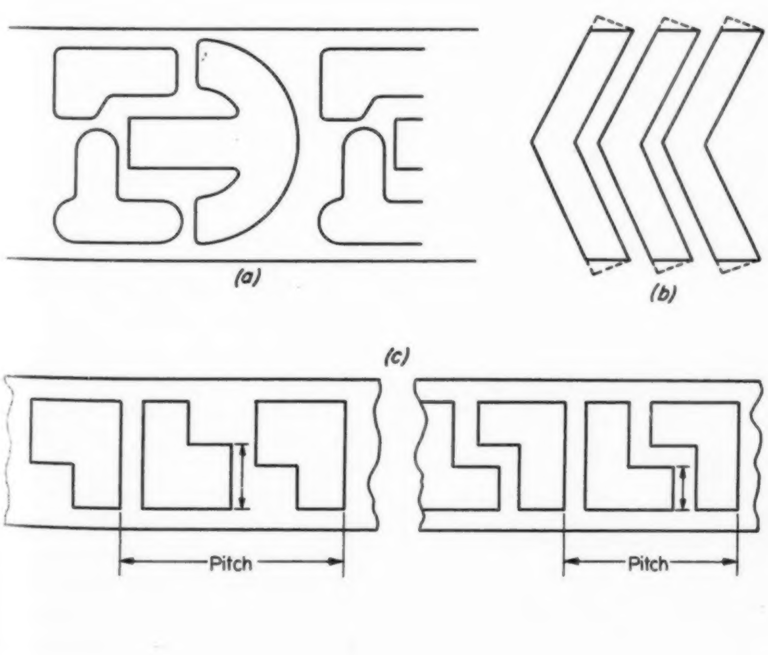


16

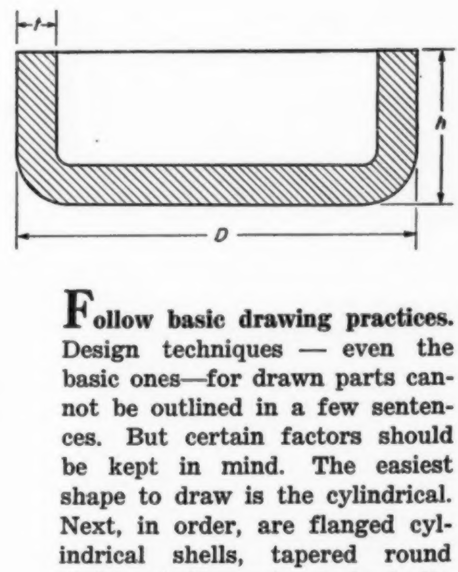
Specify wide tolerances. Although tolerances down to ± 0.001-inch can be held on holes, hole locations, outside dimensions, etc., these narrow tolerances require additional work and careful handling which increase production costs. Production tolerances of ± 0.005-inch are possible and can be held where necessary. Tolerances of at least ± 0.010-inch are much better where they can be used. Blanking tolerances should be plus, since the die becomes larger after each regrind.

17

Don't waste stock. Parts should be designed for most efficient use of the stock. If possible, parts required in equal quantities should be designed so they can be "nested" together during stamping, the normal scrap loss from one being used to produce the other, *a*. Cutting the edges of a workpiece, when function of the part permits, may save stock, *b*. Changing the dimensions to fit the actual stock width used, *c*, can sometimes result in heavy saving of material.



18



Follow basic drawing practices. Design techniques — even the basic ones—for drawn parts cannot be outlined in a few sentences. But certain factors should be kept in mind. The easiest shape to draw is the cylindrical. Next, in order, are flanged cylindrical shells, tapered round shells, half-round (spherical), square-section parts, rectangular-section parts, and irregular shapes. For easiest production and lowest tool cost, ratio between shell height h and shell diameter D should be the lowest possible. Ratio between stock thickness t and shell diameter D should be the highest practical. Other conditions being equal, thicker stock is easier to draw than thinner metal, within reasonable limits of course.

Selecting Synthetic Rubber

for Hydraulic-Fluid Service

DESIGN ABSTRACTS

By H. C Crosland
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PROBLEMS encountered in sealing hydraulic fluids have always been of concern to both the engineer and the rubber compounder. These problems have been as multiplied with the advent of the various synthetic fluids as they had been simplified with the advent of the various synthetic rubbers. This discussion will consider the proper synthetic rubber to be used with each basic type of hydraulic oil and the limitations put upon this compatibility of rubber and fluid by temperature, pressure, and other conditions of application.

Synthetic polymers currently available to the rubber compounder include nine basic types. They are the polysulfides, nitrile rubbers, chloroprenes, styrenes, isoprenes, polyacrylates, silicones, and the trifluorochloroethylene and tetrafluoroethylene (plastic) resins, *Table* 1.

There are rapidly coming into the picture two very new materials which already hold promise in the field of hydraulics — Poly FBA, made by Minnesota Mining and Mfg. Co., and vulcanizable Kel-F or Kel-F elastomer, manufactured by M. W. Kellogg.

Table 1—Basic Types of Synthetic Polymers

1. **Polysulfides** (Thiokol)
   Characterized by low physical properties and high cold flow, these polymers have excellent oil and fuel resistance with good low-temperature properties. However, due to high cold flow and low physical properties, they are not widely used in hydraulic fluid sealing applications.

2. **Nitrile rubbers** (Paracril, Hycar, Chemigum, Butaprene)
   These rubbers have excellent oil and fuel resistance and can be compounded to cover a broad range of applications from −65 F to pressure-cooker temperatures. This versatile polymer is available in various grades, each grade designed for a particular volume-change range with a corresponding temperature range. Furthermore, it can readily be handled in production.

3. **Chloroprenes** (neoprene)
   Having good oil resistance, these polymers can be compounded for excellent low compression-set characteristics. They are particularly suitable for applications where the part may require good "knitting" characteristics, such as the manufacturing of dust boots. They also lend themselves to applications requiring good resistance to ozone and weathering.

4. **Styrenes** (GR-S)
   These rubbers are increasing in importance. They are used mainly in automobile tires and other general rubber items which otherwise might be made from natural rubber. They are good in seal applications where hydraulic brake fluid is used.

5. **Isoprenes** (GR-I or butyl)
   These polymers are important in sealing some of the new fire-resistant hydraulic fluids, but their main use is in automotive inner tubes. Butyl is used for this application because of its extremely low diffusion rate.

6. **Polyacrylates or polyacrylics** (Hycar PA, Acrylon)
   Characterized by good oil resistance in applications up to 350 F, these polymers have poor low temperature characteristics and only fair overall physical characteristics.

7. **Silicones**
   Having an excellent temperature range of usefulness in dry applications, these rubbers have only fair oil resistance at high temperatures. They show some promise in sealing applications involving some of the new hydraulic fluids. The new sulphur-cure silicones may develop new uses.

8. **Trifluorochloroethylene resin** (Teflon, Fluorothene)
   Characterized by chemical inertness, this polymer is usable over a range of −100 F to 400 F. This material has been the answer to many difficult sealing problems.

9. **Tetrafluoroethylene resin** (Kel-F)
   This polymer is very similar to the trifluorochloroethylene resin.

Hydraulic Fluids: The various synthetic polymers are easy to identify. The hydraulic fluids pose a different problem. Types of fire-resistant fluids available are listed in *Table* 2 with brief discussions of what synthetic rubber compounds can be used with what fluids, and when.

A good hydraulic fluid must be nontoxic and nonfoaming. It must have some lubricating value, a constant viscosity index, and a low-temperature pour point. It must be stable, compatible with other fluids, and yet separable from injurious fluids that enter the system. Also, points to be considered are compressibility, coefficient of expansion, specific gravity and effect on packings.

Finally, a brief review of the regular hydrocarbon type hydraulic fluid will perhaps help clarify thinking regarding the fire-resistant fluids. It will also indicate the problems involved when changing a hydraulic system from regular fluid to a fire-resistant fluid.

The hydrocarbons, of which Univis J43 (covered by MIL-O-5606—the old AN-VV-0366b) is the best example of an aircraft hydraulic oil and Texas Regal oil is a good example of an industrial hydraulic oil, present no particular problem when equipment is to operate at normal temperature, say from zero to 200 F. A low-swell Buna N base

Table 2—Types of Fire-Resistant Hydraulic Fluids

1. **Halogenated hydrocarbon** (RPM)
   Data to date indicates these fluids are rough on synthetic-rubber packings. From temperature ranges of zero to 250 F a low-swell Buna N compound would be feasible. Thiokols, neoprenes or silicones could not be recommended. Teflon or Kel-F, if correctly designed, can be used with this fluid as well as with any of the other fluids.

2. **Phosphate ester** (Skydrol, Pydraul F-9)
   Seals that are recommended for hydrocarbon base fluids are not usable when a switch to the fire-resistant phosphate esters is made. However, seals and packings made from butyl rubber or silicone are entirely satisfactory at temperatures up to 212 F or more.

3. **Water glycol types** (Hydrolube U-4 or 200N, Houghto-Safe)
   These fluids give little trouble on all types of sealing applications in hydraulic systems. Depending on the type of seal required and the temperature range involved, Buna N, neoprene, silicone or butyl are all satisfactory with this class of fluids.

4. **Silicone oil** (General Electric, Dow-Corning)
   These fluids are very good because of their excellent viscosity index. Sealing this class of fluids is more a design problem than a compounding one. Most synthetic rubbers in contact with silicone fluids will shrink. The low acrylonitrile content of Buna N's causes a very low shrinkage when in contact with the fluids. Also, the use of silicone fluids having viscosities in excess of 100 centistokes will help, since they have less effect on the rubber than the low-viscosity ones.

5. **Tricresyl phosphate** (Lindol HF)
   Better known as TCP, this fluid is used in automobile hydraulic systems. Normal sealing applications can be adequately taken care of by the use of butyl rubber base synthetic rubbers. In some cases, silicone base compounds have been used successfully. Above 212 F either of the compounds become softened.

6. **Chlorinated diphenyl** (Arochlor 1248)
   At room temperature, Buna N, GR-S, butyl rubber or silicone base compounds are satisfactory with these fluids. As temperatures increase, however, only the silicone base compounds are recommended.

7. **Soluble oils** (Shell Drumas A, Standard C60)
   None of these fluids present any particular problem for sealing applications. Buna N's, neoprenes and silicones can all be used for this group of fluids, and they can be properly sealed through a temperature range of −65 to 350 F with the organic polymers. The temperature range can be enlarged with the use of Teflon and Kel-F.

compound or a neoprene compound can be used for packings, seals or gaskets.

The low-swell Buna N would be one characterized by high acrylonitrile content in the copolymer. Should the equipment be required to operate at temperatures of below zero F to, say, −65 F, then a low-temperature Buna N could be used. A low-temperature Buna N would be characterized by one with a low acrylonitrile content. However, the low-temperature Buna N has a higher volume swell. With a gasket application this might not be serious, but on a packing or a seal, this must be thoroughly checked prior to use.

In applications in which temperatures go to 350 F, then a polyacrylate base synthetic rubber could be used. However, low-temperature flexibility is lost. If the use of the fluid is between zero and 350 F, the polyacrylate compound will work fine. Volume change will be slightly higher than that obtained with a low-swell Buna N, but not so great as to make the use of the polyacrylate compound prohibitive.

Silicones can be used for some high-temperature applications involving packings and seals, but must be carefully engineered for the job.

When packings are required for use in a hydrocarbon type fluid, the packing supplier can better help select the right material if he is supplied the aniline point of the fluid used. This is an indication of the effect the oil will have on the polymer. This aniline point can be obtained from the manufacturer of the fluid or the packing supplier can obtain it from a sample of the fluid.

This covers the "marriage" of the types of polymers and the type of fluids. It is difficult to give specific recommendations. Each application is an individual one and must be treated as such. A compound that may be suitable for one fluid at room temperature may not be suitable in another application at 200 F. A seal built to operate at 200 F may be a very costly seal due to design or polymer used and because of this high cost may be out of the question, economically, on the room-temperature application.

From a paper entitled "Effect of Hydraulic Fluids on Synthetic Rubber" presented at the 10th annual National Conference on Industrial Hydraulics in Chicago, Ill., October, 1954.

Applications for

Reinforced Plastic

By Robert W. Matlock
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REINFORCED plastic is not cheap. Preform-type moldings, with chopped fibers for reinforcement, have a material cost of approximately 50 cents per lb, including waste. The finished part price on long production runs from matched steel dies may be taken as about \$1.00 per lb. Aircraft-quality parts of a glass-cloth laminate, void-free construction, may have a material cost of \$2.00 per lb, and a finished part price of from \$5.00 per lb to \$20.00 per lb.

It is apparent from these figures that reinforced plastic is used, not because it is inexpensive, but because it has certain merits which in a given application outweigh its cost disadvantages.

Physical Properties: The fact that reinforced plastic has high physical properties is well known. Because of its high tensile and flexural strength, as well as a low modulus of elasticity, its impact strength is particularly good.

The disadvantages consist of a

low modulus of rigidity and many possible combinations of resin, reinforcement, and fiber direction that make it difficult, if not impossible, to publish complete physical properties. Various desirable properties of reinforced plastic are listed and briefly discussed in *Table* 1.

Applications: Listed in *Table* 2 are several applications which have successfully utilized reinforced plastic. Opposite each application is a list of desired properties, with a number denoting those of importance for the particular item. Since advantageous use of desirable properties creates a good application, it must then be true that a great advantage will outweigh a small advantage, and that a disadvantage will have a negative value. The number of properties utilized is, therefore, not conclusive. It is necessary to weigh properly the various factors in accordance with their importance, and to include negative factors for disadvantages compared to other materials. These weighted factors are indicated in *Table* 2.

If a property is required or highly desirable, it is given a weight of 3. If it is needed, a factor of 2 is used. If the property is desirable, a factor of 1 is assigned. Negative factors can be given the same values in reverse. It is extremely unlikely that it will be necessary to consider negative values greater than 1. If great disadvantages exist, reinforced plastic will probably not be under consideration.

Having assigned numerical values according to the importance of the properties used, several facts may be noted from *Table* 2. The largest value is 11, and the smallest value is 4. It is not probable that any application could achieve more than 12 points. And it is not likely that any application could gain favor with less than 4 points.

Since gas-meter housings and cases, although not entirely new items, have yet to prove themselves as good applications, it may be concluded that 5 points makes for a marginal application.

The average value is approximately 7. Since the two items given a value of 7 have been highly successful, it is apparent that any product having 7 or more points may be an excellent application for reinforced plastic.

Design Aids: The method of analysis described is for one purpose only—to aid the design engineer in recognizing an application for reinforced plastic. It is not a positive formula, nor does it by any means include all factors required for a decision.

As an example, consider an application where reinforced plastic is almost mandatory—the liners of aircraft self-sealing fuel-cell cavities. In this case, the maximum number of points which can be assigned is 4. However, metal has the tendency to "flower" when pierced by a bullet, whereas reinforced plastic simply tears. Since flowering of the metal will prevent the hole in the self-sealing tank from closing and therefore sealing, it cannot be used. This creates an excellent application for reinforced

Table 1—Design Considerations for Reinforced Plastic

1. Light weight

Reinforced plastic weighs approximately 0.065 lb per cu in., roughly one-fourth the density of steel, two-thirds that of aluminum or the same as magnesium.

2. High corrosion resistance

Reinforced plastic is not affected by a great variety of solvents, chemicals, etc., other than strong or fairly strong acids and alkalies. Some resins are more resistant to certain chemicals than others. An important factor is resistance to environmental substances such as water and salt.

3. Excellent formability

The material can be formed into complex shapes almost as readily as into simple shapes. Also, a few parts may be hand-formed on relatively inexpensive tooling.

4. Useful electrical properties

Reinforced plastic has excellent insulating properties and the ability to transmit microwave energy efficiently. Moisture absorption is very low.

5. Important appearance factors

Beautiful and unusual effects have been achieved by combining glass fibers and resin. Some of the textured surfaces and moldings containing fabrics as face plies are particularly interesting. Because color can be added directly to the resin, no surface finish is necessary or desired and the original appearance is more easily preserved.

6. Low thermal conductivity

Thermal conductivity is lower than that of metals.

Table 2—Weighted Factors for Applications of Reinforced Plastic

Item	High Physical Properties	Low Specific Gravity	Chemical or Corrosion Resistance	Formability or Ease of Fabrication	Electrical Properties	Beauty of Appearance	Low Thermal Conductivity	Total
Radome	3	3	1	1	3	..	..	11
Boats	2	2	3	2	..	..	..	9
Tote box	2	2	..	..	..	..	..	4
Auto body	2	2	..	2	..	..	..	5*
Corrugated panel	2	1	3	..	..	3	1	10
Pipe	2	1	3	..	..	..	..	6
Washing-machine tub	2	..	2	2	..	..	..	6
Truck tank	2	2	2	..	..	..	..	6
Gas-meter cover	1	..	2	..	..	2	..	5
Radar scanner	2	2	..	2	..	..	..	6
Aircraft duct	2	2	..	3	..	..	..	7
Cases	2	2	†	†	†	†	†	5
Electrical flat sheet	2	..	2	..	3	..	..	7
Aircraft fuel-cell liners	2	2	..	..	..	..	..	4

*Includes a negative factor for paint. †Occasionally used properties given total weight factor of 1.

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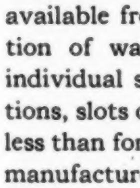
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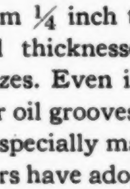
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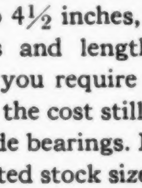
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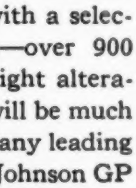
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On the other hand, there may be some requirement, such as 1000 F ambient temperature, which will prevent the use of reinforced plastic, even though a high numerical value may be achieved. For example, there have been a few radomes where optical transparency was a requirement. In these cases, material was used which would normally never have been considered.

From a paper entitled "Recognizing Applications for Reinforced Plastic" presented at the ASME Annual Meeting in New York, November-December, 1954.

Developing and applying

Pneumatic Control Valves

By S. Y. Lee and J. L. Shearer
*Assistant Professors of Mechanical Engineering
Massachusetts Institute of Technology
Cambridge, Mass.*

EARLY in 1951 a strong interest developed in utilizing highly compressed gas (500-2000 psi), instead of hydraulic oil, as the working fluid in valve-controlled servomotor systems. Except for low-pressure (10-20 psi) pneumatic control systems that have been developed for industrial process controls, compressed gases seldom have been used in the continuous control of motion required in many modern servomechanisms and automatic control systems. Compressed air often is applied to simple, on-off control functions in systems where mechanical stops are provided for positive positioning action.

Continuous control systems that have been developed for operation with compressed air are largely low-pressure instrument systems in which speed of response is not a critical factor and in which maximum power controlled is usually of the order of a small fraction of one horsepower. Flapper-type and poppet-type valves have proven satisfactory for controlling flow of air in these systems. Pressures are so low that little difficulty is encountered in overcoming the forces exerted by the fluid on the moving member of the valve. Dynamic performance of these low-pressure systems usually can be determined with the same fundamental equations that are used for the flow of hydraulic fluid because the pressure drop across each orifice is much smaller than that required to produce sonic velocity in the fluid stream.

Early analytical work with high-pressure pneumatic systems was hampered by the existence of fluid compressibility in the control orifices and working chambers of the systems. Lack of ability to produce tangible analytical results in a short time did not prevent trying to operate, with compressed nitrogen at 1000 psi, a valve-controlled servomotor employing a spool-type valve that had been operating successfully with hydraulic oil. This system is shown schematically in *Fig.* 1. Early tests with nitrogen revealed surprisingly good performance when the valve was adequately lubricated so that it would be easily stroked by the electric torque motor which had been provided for use with the hydraulic system. The oil remaining from previous operation as a hydraulic system served as a satisfactory lubricant for short periods of time, but the gas eventually carried all the oil away and caused the valve to stick.

Hydraulic versus Pneumatic Operation: A qualitative appraisal

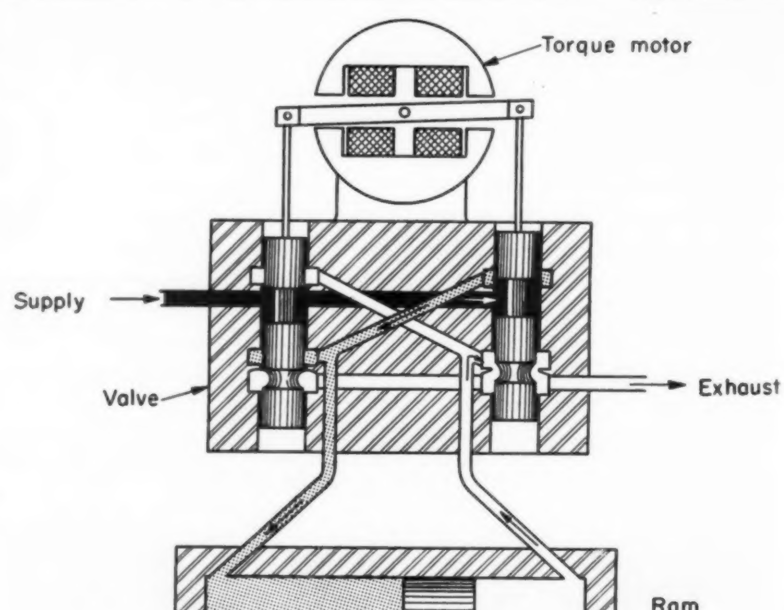

Fig. 1—Schematic drawing of a valve-controlled servomotor employing a spool-type valve

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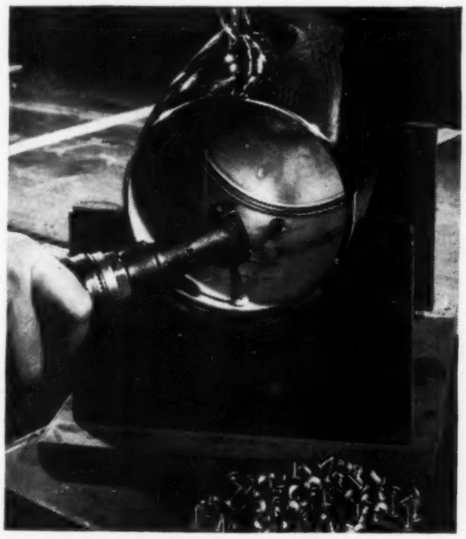

IN "BLIND" LOCATIONS. A product engineer of Dominion Electric Corporation reports, "Phillips screws permit us to design appliances in which screws can be inserted in 'blind' locations. Also they definitely speed our production and improve product appearance."

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MINIMUM REJECTS. In The Wiremold Company's "Plugmold", Phillips screws assure a tighter assembly and more positive electrical contact. "Besides being neater and easier to use," says the Wiremold plant engineer, "Phillips screws have reduced our rejects to a negligible amount. Under no conditions would we use any other type screw."

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of the two modes of operation can be made on the basis of overall system complexity, availability of working fluid, efficiency, dynamic performance, limitations of working temperature, lubrication of moving parts, susceptibility of working fluid to contamination, and safety of operation.

Where operation with a ram-type motor is possible, the complexity of the two systems seems about the same. A hydraulic system requires a pump, pressure controller, sump, filter, and heat exchanger in the fluid power supply. The corresponding pneumatic system requires a multistage compressor with interstage cooling, pressure controller, air filter and dryer. Since atmospheric air is usually available as the working fluid in a pneumatic system, return lines and a sump are unnecessary. Therefore, the pneumatic system has an advantage in this respect.

Since good hydraulic fluids are expensive and also perhaps flammable, all external leaks must be eliminated in a hydraulic system. Experience has shown that this is difficult. Minor external leaks in a pneumatic system do waste power but give no trouble otherwise. Internal and external leakage waste power in either system, but power loss due to leakage is potentially greater in pneumatic systems because more work is required to compress air than oil. Because of the greater work required to pump a compressible fluid to a given pressure, the energy dissipated due to pressure drop across the orifices in control valves is greater in pneumatic systems. This factor is significant since a valve can maintain effective control of fluid flow only by its ability to dissipate part of the energy of the flow.

The working temperature of hydraulic systems is usually limited by freezing of the hydraulic fluid at the lower end of the range and vaporization of the hydraulic fluid at the upper end of the range. Variation of hydraulic-fluid viscosity can have a serious effect on flow of fluid in the system and on the ability of components to handle it; that is, pump cavitation, leakage flow rate and wear are accelerated by high-temperature operation, while line losses and valve stroking forces are high at low temperature operation. On the other hand, the working temperature of pneumatic systems is limited only by the characteristics of the components which carry it, and this makes possible a much wider range of operating temperatures. Within this range, the variation of viscosity with temperature is much less than that of a hydraulic fluid; furthermore, viscosity is less than that of liquids. Adequate low-friction seals between moving members are hard to achieve unless some lubricant can be provided at the sealing point. Materials currently available for sealing members tend to limit the upper operating temperature of pneumatic control systems.

Because of the more compliant nature of compressed air, a pneumatic system might not have as fast a dynamic response as a hydraulic system, and fluid compressibility probably would be significant in many applications.

Adequate lubrication of control valves and other moving parts is of utmost importance. This lubrication is usually provided by a good hydraulic fluid. Compressed air, by virtue of its low viscosity and negligible lubricity is a poor lubricant unless used in a hydrodynamic bearing with high relative speeds between the moving parts or as a pressurized film as in an externally pressurized bearing.

Contamination of the working fluid seems to provide the same potential difficulties in both hy-

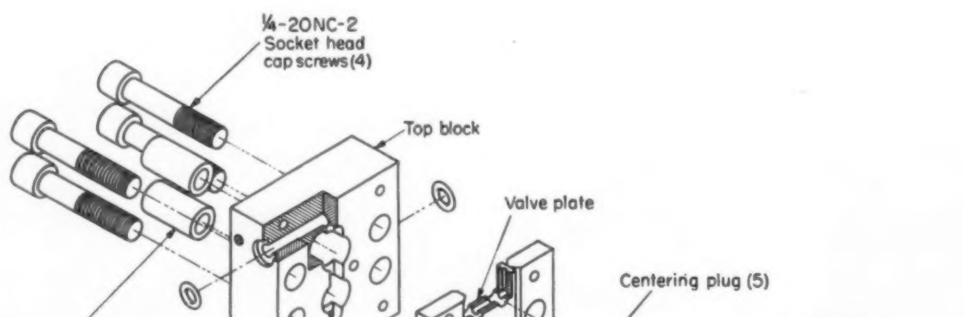
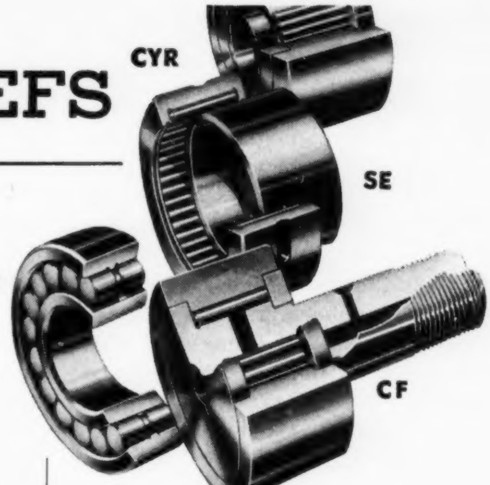
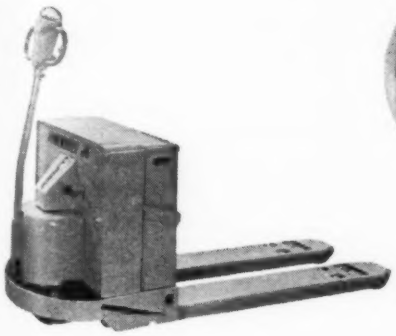
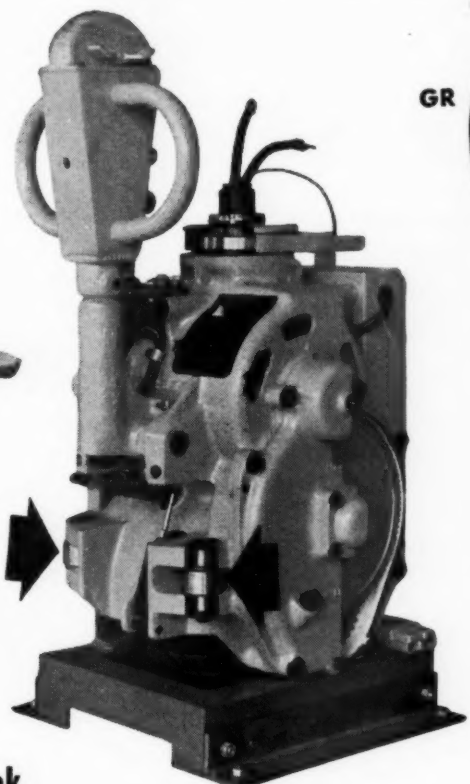


Fig. 2—Exploded view of sliding-plate valve using hole, slot and plug-type construction

McGILL BEARING BRIEFS







Sealed **GUIDEROL**® bearings meet design demands of Clark *POWRWORKER* hand truck

The power head in Clark Equipment Company's Powrworker trucks required a bearing to provide radial support to the wheel-mounted pivoting drive unit. In addition it had to seal out dirt, carry a sizeable load in limited space and adapt to vertical mounting. Sealed GUIDEROL bearings meet each of these requirements.

For instance, the bearings are only $4\frac{1}{2}$ inches above the floor and in contact with contaminating materials such as dirt, chemicals and brine that would freeze up ordinary unsealed bearings. Use of the Sealed GUIDEROL bearings eliminates the need for multiple parts and extra machining of the housing that would be required with auxiliary sealing of an ordinary bearing.

Although limited in size by the fit of the unit into the truck, the GUIDEROL SG Bearings take loads up to 1,500 pounds in absorbing starting and stopping inertias of the truck and the unit.

The SG Series bearings operate perfectly and last longer in vertical mounting because the center guided construction provides a guide rail that keeps the grooved rollers in alignment under any load from vertical to horizontal. They are available with built-in single and double seals with no increase in standard Guiderol bearing width.

To help insure product performance and to simplify production and assembly, investigate Sealed GUIDEROL Bearings today.

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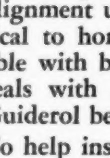

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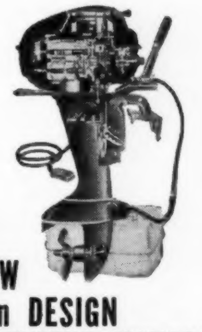

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draulic and pneumatic systems. Dirt and foreign particles cause sticking of control valves and tend to accelerate wear in seals and in pumping members. Dirt might be a more serious problem in a pneumatic system because relatively dirty atmospheric air is drawn in, filtered, used, and exhausted, with little chance that it ever will be used again. Filters might require more frequent replacement in a pneumatic system.

Except for the fire hazard with flammable liquids, hydraulic systems seem to be somewhat safer than pneumatic systems. Small amounts of oil at any point of elevated temperature in a pneumatic system can cause an internal explosion which may rupture the walls of the system. Any break due to defective materials, manufacture, or assembly could have most serious consequences in a pneumatic system where the working fluid must expand to many times its compressed volume before it reaches equilibrium at atmospheric pressure.

Pneumatic Valve Design: Leakage flows causing serious loss of energy must be kept small. This means that each of the control-valve orifices must be as nearly closed as possible when no flow is required to drive the load. And, at the same time, the size of all possible leakage paths from the high-pressure passages to the atmosphere must be kept to a minimum. Although flow characteristics of an orifice are not linear, a slide-type variable orifice is an effective means of controlling fluid flow because a large change in resistance to flow can be obtained with a small valve motion. Definite clearance which must be provided to permit relative motion between the fixed and moving parts of a valve results in control-valve orifices that never completely close and also in leakage paths that lead from the high-pressure regions in the valve to the atmosphere. Therefore, the clearances must be kept to a minimum.

In a valve containing two or more metering or control orifices acting in unison, all orifices should open and close at precise valve positions; this means that very accurate alignment of the edges of the metering orifices is required. For example, an overlap condition in a four-way valve leads to a dead-zone type of action in that practically no change in orifice area will occur for small motion of the valve about its center position. An underlap condition, on the other hand, leads to excessive leakage when the valve is centered.

While relatively small motion of the valve will bring about relatively large changes of flow resistance in the valve, it is also desirable to be able to stroke the valve with the smallest possible force. Friction between the fixed and moving parts of the valve usually is the largest component of force which opposes motion of the valve. Because the density of compressed air at pressures up to 1000 psi is much less than that of hydraulic oil, the fluid flow forces are probably negligible in most systems supplying less than 10 horsepower to the load. The force required to accelerate the moving parts of the valve should be as small as possible. A short valve stroke and small moving parts are desirable from this point of view. Friction in the valve can be minimized by eliminating metal-to-metal contact in the clearance spaces and by providing a working fluid that is free of foreign particles. It is not possible to open the clearances to handle a dirty fluid unless greatly increased leakage flows can be tolerated.

In a system employing a four-way valve, relative sizes of the upstream and downstream orifice areas are important because the ratio of upstream to downstream orifice area when the valve is centered determines the quiescent pressure in the ram or motor lines, and therefore the fluid compliance of the system. It is usually important to make this quiescent pressure a substantial fraction of supply pressure in order to obtain the best dynamic performance from the system. Port widths should be chosen so that the maximum stroke of the valve is large compared with the possible inaccuracies that might be encountered in the alignment of the metering orifices. Many applications require that areas of valve orifices be related to the valve stroke.

Operation of the valve should not be sensitive to stresses caused by its means of mounting, thermal gradients, aging or way of connection to fluid lines.

Development of Pneumatic Valves: Plate valves employing the hole, slot, and plug construction have been found to meet the design requirements of pneumatic systems much better than spool-type valves. Proper alignment of the metering orifices can be attained by machining the valve plate and bushing holes with the parts clamped together or by machining the parts separately with carefully made jigs or fixtures. In *Fig.* 2 an exploded view of a slid-

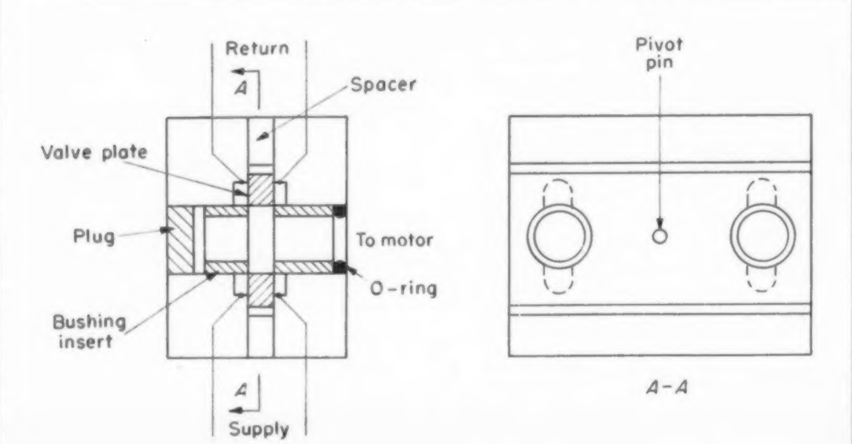
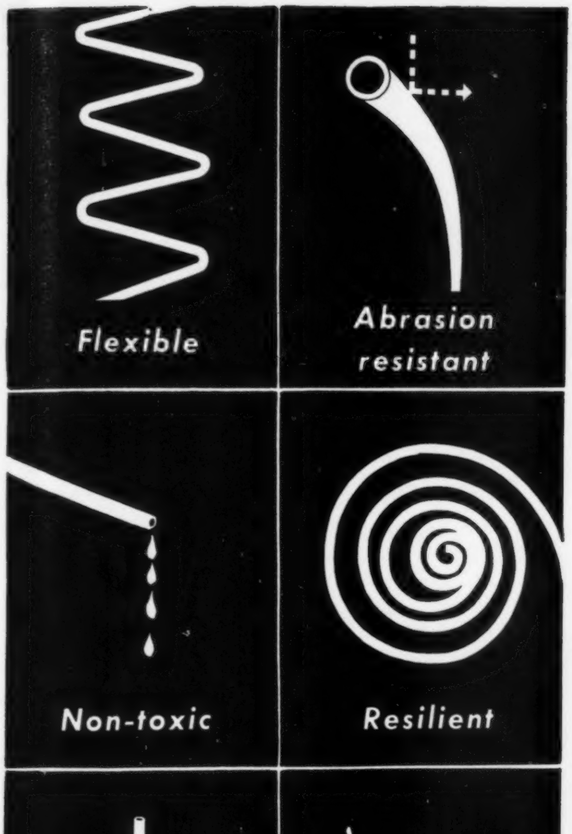


Fig. 3—Schematic drawing of rotary-plate valve



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NYLAFLOW tubing is now available in stock diameters and lengths. There are two grades: Type T with a tested bursting strength of 1,000 psi; and Type H, 2,500 psi. The tubing also is available in colors for color coding.

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ing-plate valve illustrates how a symmetrical construction is used to balance out the pressure forces. Spacer plates provide proper clearances, guide the valve plate so that it moves only in its proper direction, and provide alignment of the valve blocks with the aid of dowel pins.

In order to minimize metal-to-metal contact between the moving valve plate and the valve blocks, small plugs are pressed into holes in the valve plate. The centers of these holes are connected with the pressure supply. The plugs are provided with small grooves which have flow resistances roughly equal to those of the leakage paths outward through the clearance spaces. If the valve plate moves upward, for example, the average pressure above the plate increases and that below it decreases, thus producing a force which tends to recenter the plate. Five centering plugs were employed as shown in *Fig.* 2 to provide proper centering action for this valve.

The rotary-plate valve shown in *Fig.* 3 illustrates how the same principles of construction have been applied to a valve in which the plate rotates slightly about a pivot pin instead of sliding axially. Although this design is more complicated in that accurate alignment of the pivot pin must be provided, it is insensitive to linear accelerations.

In studies of the performance of valves under various flow conditions, the pressure-flow characteristics of each pair of orifices have proved to be useful measurements. The pair of orifices formed by the hole, slot, and plug construction at one end of the valve plate completely controls the flow to or from one motor line. Systematically measuring this flow as a function of motor-line pressure and valve displacement provides a family of curves such as that shown in *Fig.* 4. The data for *Fig.* 4 were obtained from tests made on one end of the valve shown in *Fig.* 2.

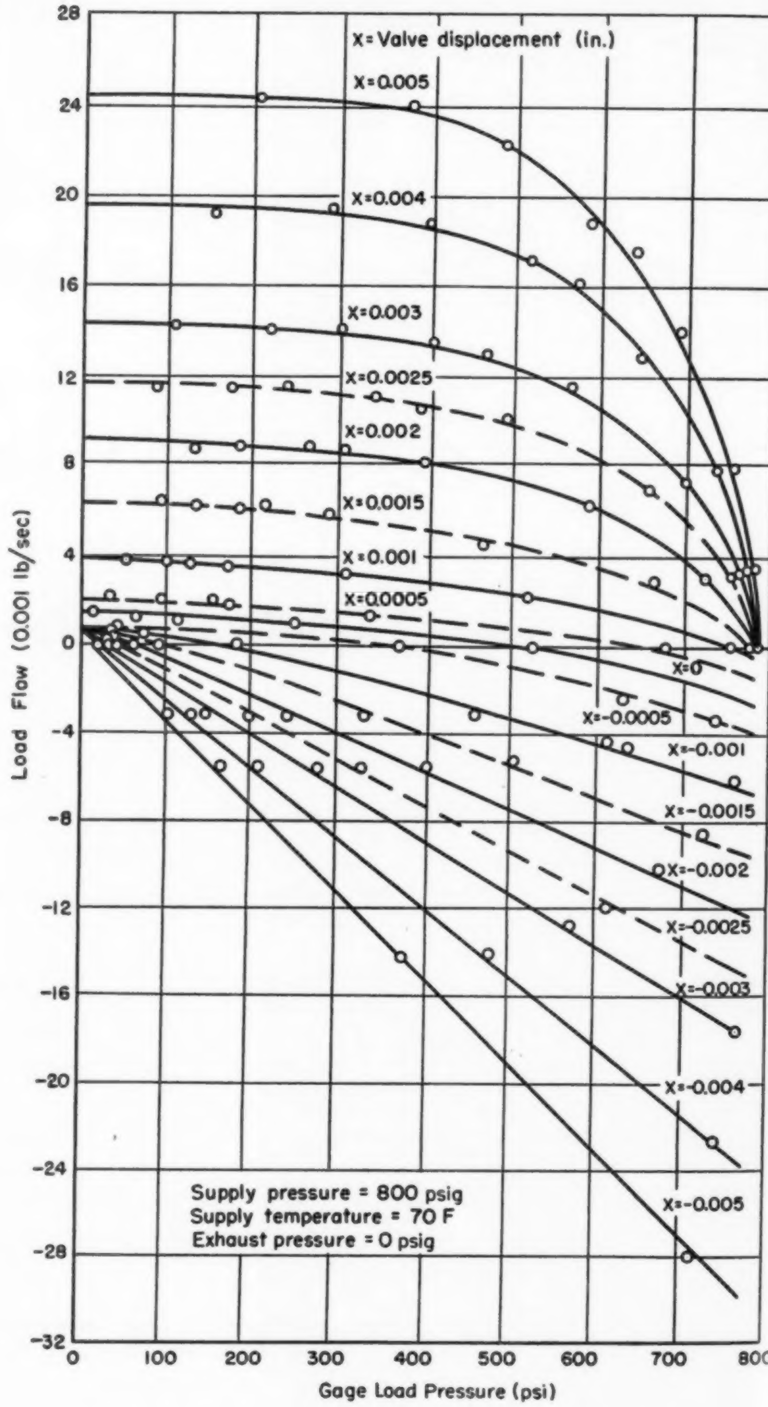
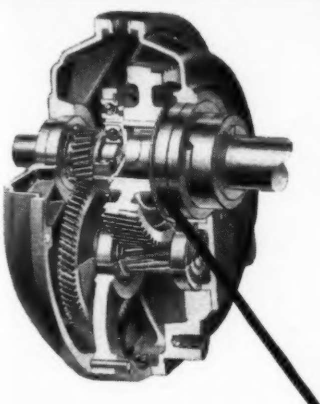


Fig. 4—Measured pressure-flow characteristics of sliding-plate valve

High-Pressure Electropneumatic Servomechanism: The rotary-plate valve was developed for use in the feedback control system shown in *Fig.* 5. Here an electric signal voltage serves as the input quantity, and output position is measured electrically by a linear differential transformer, amplified, and fed back to compare with the input signal. A power amplifier drives a torque motor from the error signal. This servomotor package, which measures approximately $3\frac{1}{2}$ by $2\frac{3}{4}$ by 2 inches, operates with air supplied at 1000 psi to the rotary-plate valve and a maximum current of 40 ma at 80 volts to either winding of the permanent-magnet torque motor. The maximum stroke of the valve and torque motor is 0.007-inch and the

Heart of this machine mounts on the shaft!



American Shaft-King features three-wall, internally-ribbed housing to hold gears and bearings in perfect alignment, provide extra-capacity oil reservoir. Leak-proof, anti-friction sealing system keeps air in—dirt out. Patented concentric-shaft design puts oil level below input shaft and output hub. Bearing *seals do not operate* against *a head of oil* . . . an exclusive Shaft-King feature.

If you operate belt, chain or screw conveyors, mixers, agitators, canning equipment—*any* process which demands *precise* slow speeds—American's Shaft-King is the logical speed-reduction drive for you. It's 98% efficient, turns out the exact RPM you need from 154 down, handles requirements through 40 HP.

Shaft-King mounts directly on standard shaft extensions, needs no supports, no costly, time-wasting engineering to install, remove or relocate. Patented concentric-shaft design permits positive, instantaneous overload protection with a Torque-arm overload release. Also available with a built-in backstop.

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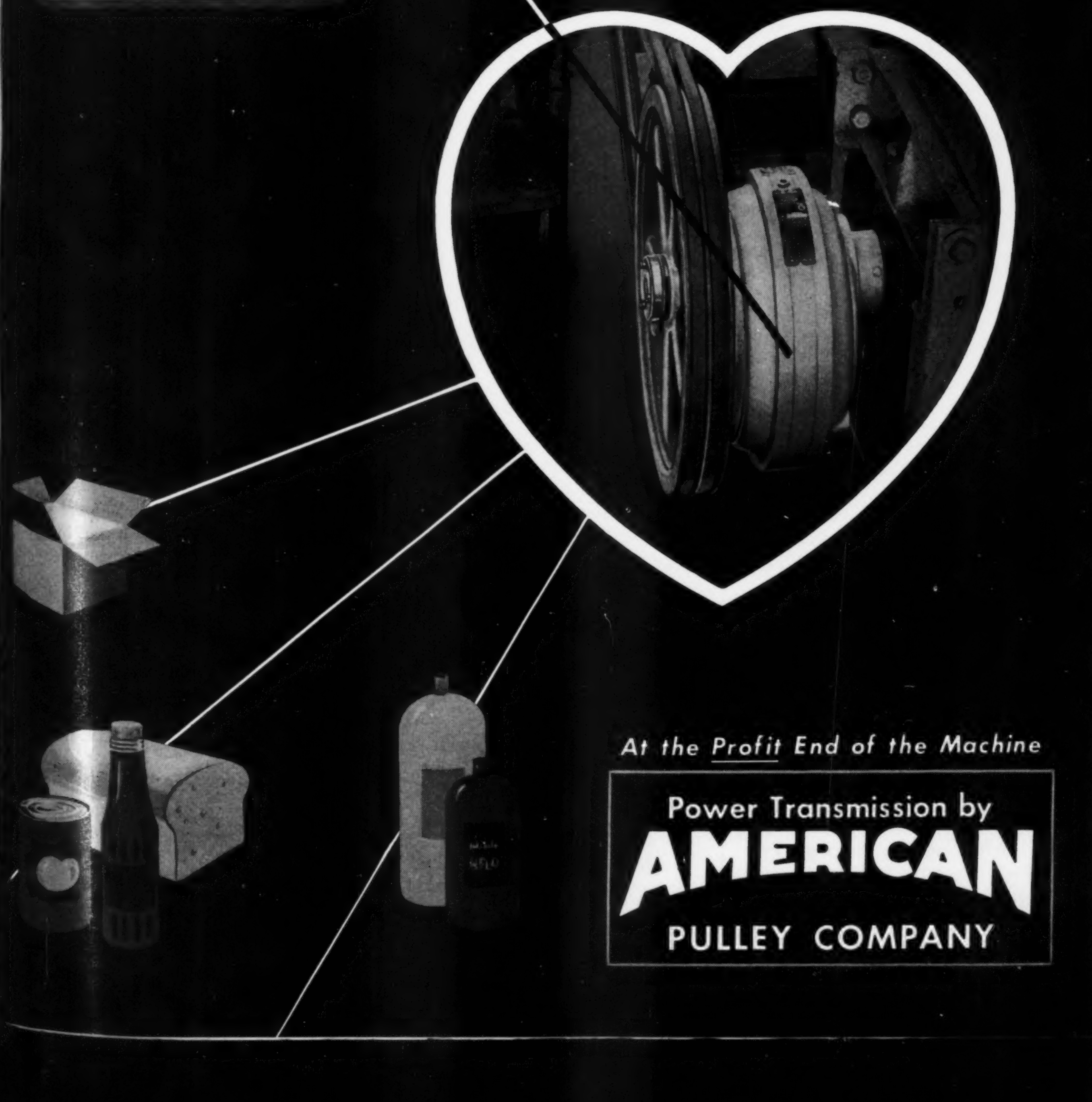

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torque motor strokes the valve with an available maximum force of about 5 pounds. The total upstream port width at each end of the valve is $\frac{1}{4}$-inch, and the total downstream port width at each end of the valve is $\frac{3}{8}$-inch. The quiescent leakage flow through the valve is 0.005 lb per sec. The ram has an effective area of 0.67 square inches and a total stroke of 1.00 inch. The maximum no-load velocity of the ram is 14 in. per sec., and the maximum available pressure force at zero ram velocity is 670 pounds.

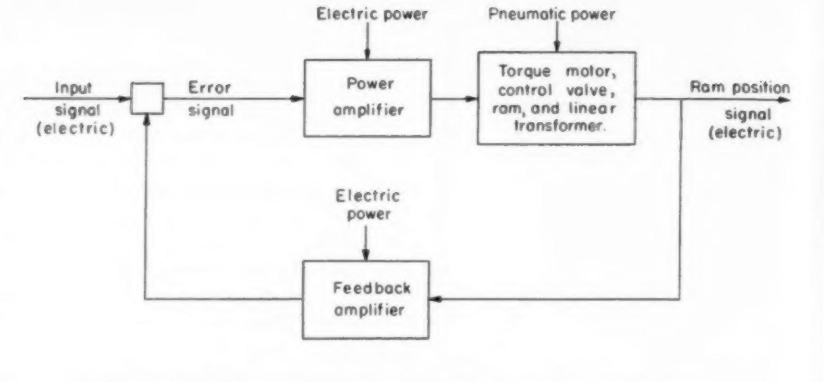


Fig. 5—Schematic diagram of electropneumatic servomechanism

Conclusions: Experience gained from using pneumatic power to control the motion of loads with various amounts of mass has shown that compressed gases can be employed effectively. The speed of response possible with pneumatic operation is always slower than that attainable with hydraulic oil, but many applications do not require higher speed of response. Although most of the pneumatic-control work that has been done in the Dynamic Analysis and Control Laboratory at M.I.T. has been with systems operating with compressed air supplied at pressures between 500 psi and 1000 psi, pneumatic control seems very promising for industrial applications operating at 100 psi to 500 psi.

From a paper entitled "Development of Valves for the Control of Pneumatic Power" presented at the 10th annual National Conference on Industrial Hydraulics in Chicago, Ill., October, 1954.

Design considerations for

Belleville Spring Washers

By H. J. Stewart

Chief Engineer
Union Spring & Mfg. Co.
New Kensington, Pa.

IN LIEU of the name "Belleville" most textbooks use the title "coned disk spring" which is more descriptive of the form or shape of this spring. Many variations in contour have been devised which contribute to the attributes of this type spring.

Possibilities in variable load-deflection curves are numerous, depending on the ratio of the dish to the metal thickness, the inclusion of scalloped edges and radial slots of various designs.

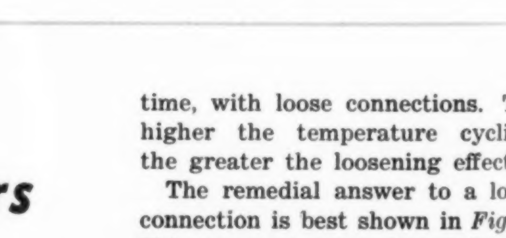
Shown in *Fig.* 1 are the comparative space requirements for a $1\frac{3}{4}$-inch by 5/32-inch Belleville spring and a helical spring having the same load capacity.

As one example, it is common practice to use steel bolts for fastening copper joints, aluminum joints and aluminum to copper joints on bus bars. Obviously, some difference in expansion and contraction between the bolts and the bus conductors will result, in time, with loose connections. The higher the temperature cycling, the greater the loosening effect.

The remedial answer to a loose connection is best shown in *Fig.* 2. This connection has four belleville spring washers, four heavy gage high-strength flat washers, and four $\frac{1}{2}$-inch high-strength steel bolts gripping a 4 inch by 4 inch lap joint.

Since these four washers have a flattened capacity of approximately 24,000 lb, (see curve in *Fig.* 3), when the nuts are backed off a few thousandths of an inch the joint is under a uniform pres-

Fig. 1—Comparative sizes of Belleville spring washer and an equivalent helical spring



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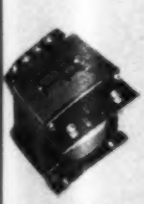
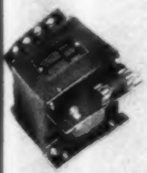
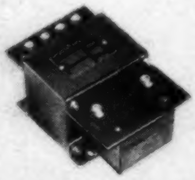
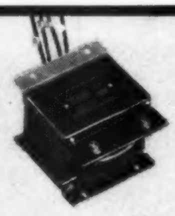
MACHINE TOOL TRANSFORMER CUSTOMER SPECIFIED ACCESSORIES GROUPS

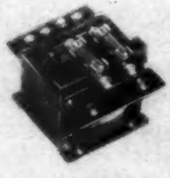
Group No.	Terminal Board		Cable Leads		Fuses			Circuit Breakers	Volt-amperes Ratings Available
	Primary	Secondary	Primary	Secondary	One	Two	Four		
G1	yes	yes	no	no	no	no	no	no	50, 75, 150, 300, 500, 750, 1000, 1500, 2000, 3000, 5000
G2	yes	yes	no	no	yes	no	no	no	50, 75, 150, 300, 500, 750, 1000, 1500, 2000, 3000, 5000
G3	yes	yes	no	no	no	no	no	yes	. . . . . . 300, 500, 750, 1000, 1500, 2000, 3000, 5000
G4	no	yes	yes	no	no	no	no	no	50, 75, 150, 300, 500, 750, 1000, 1500, 2000, 3000, 5000
G5	yes	yes	no	no	no	yes	no	no	50, 75, 150, 300, 500, 750, 1000, 1500, 2000, 3000, 5000
G6	yes	yes	no	no	no	no	yes	no	. . . . . . 300, 500, 750, 1000, 1500, 2000, 3000, 5000
G7	no	no	yes	yes	no	no	no	no	50, 75, 150, 300, 500, 750, 1000, 1500, 2000, 3000, 5000

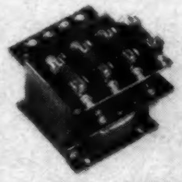

G1—Terminal boards

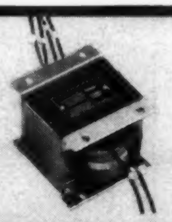

G2—Terminal boards, fused secondary


G3—Terminal boards, circuit breaker in secondary


G4—Secondary terminal board, primary leads out

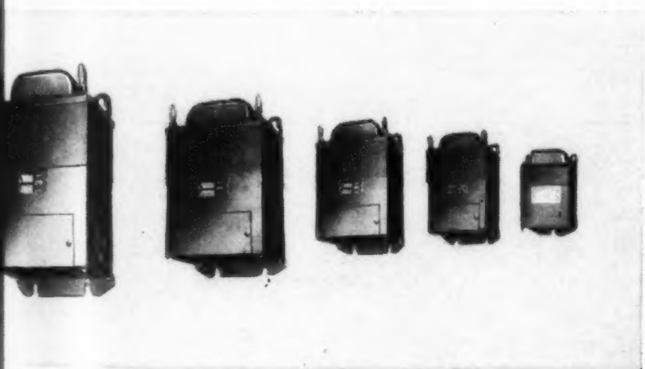

G5—Terminal boards, 2-fuse secondary board


G6—Terminal boards, 4-fuse secondary board

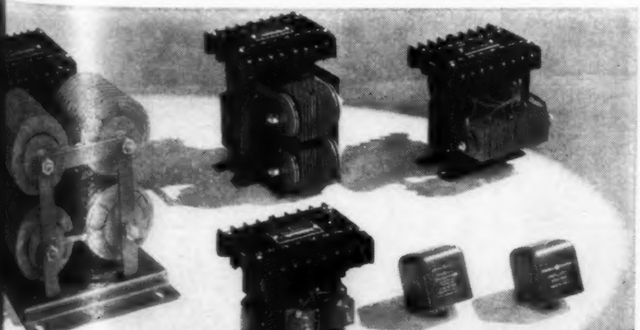

G7—Basic transformer with leads out

UNEQUALLED FLEXIBILITY of G-E dry-types is demonstrated by the new machine tool transformer design. Merely select the rating you require and specify the accessories group your customer wants. You get a "custom-tailored" unit at a stock item price.

Here's how you can meet design requirements by specifying G-E standard dry-type transformers



COMPLETE LINE of Type M transformers covers ratings from 0.25 kva through 15 kva. These transformers are designed for rugged service in a wide variety of applications, both indoor and outdoor.



AMPLISTATS, self-saturating magnetic amplifiers combine the advantages of high gain, fast response and simple, rugged construction. Available in ratings from 1 through 930 volt-amperes.

Most of your requests for G-E dry-type transformers can be filled with a standard unit, directly from stock. For example, G-E machine tool transformers are available in 22 basic designs, yet these twenty-two basic designs offer over 100 different electrical combinations—enough to meet almost any design requirement.

The same design flexibility is apparent in the rest of G.E.'s high quality specialty and general purpose dry-type transformers, such as voltage stabilizers, control and signal transformers, and saturable reactors.

General Electric submits each Type M transformer to a minimum of 18 different tests and inspections. It is this typical high quality control of G-E products that assures you of the highest quality possible.

When you need a dry-type transformer, call on your nearest G-E Apparatus Sales Office—they will be glad to help you. Or, send in the coupon and we will promptly send you more detailed information on G-E dry-type transformers.

GENERAL ELECTRIC

General Electric Company, Section A410-11
Schenectady 5, New York

Please send me the following bulletins:

☐ GEC-1270 Transformers for Control Panels & Machine Tools
☐ GED-2024 M&D Dry-type Transformers for Industry
☐ GET-2424 Amplistats

NAME ....

COMPANY ....

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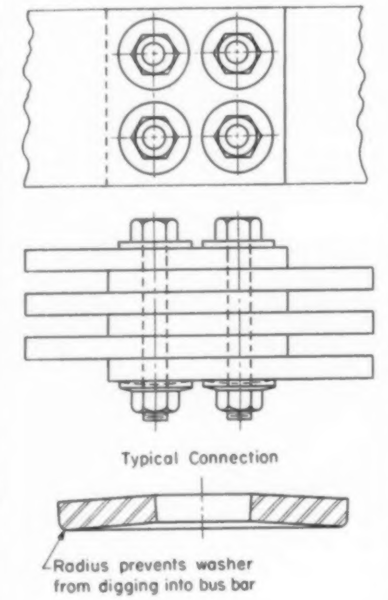


Fig. 2 — Bus bars clamped with bolts and Belleville washers

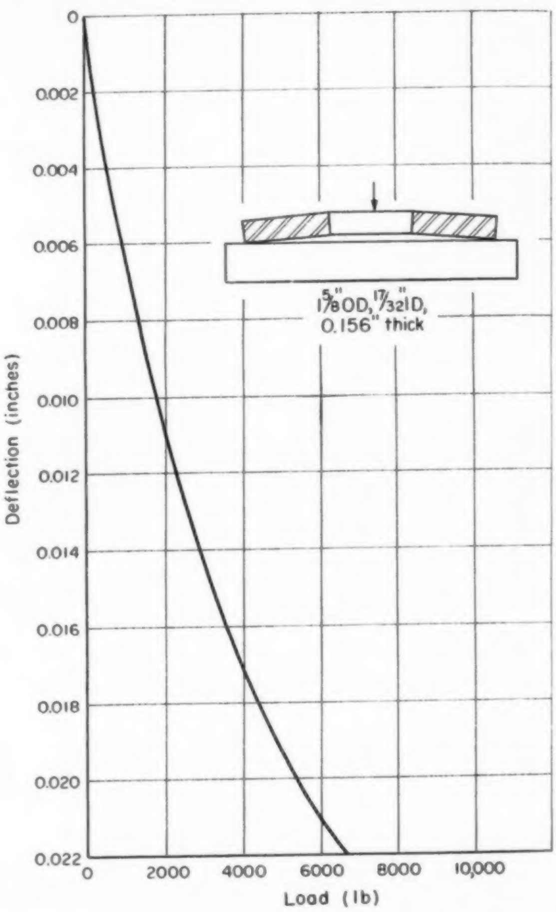


Fig. 3 — Load-deflection curve for a ½-inch Belleville spring washer

sure of about 1000 psi. This pressure remains fairly constant even though the ambient temperature may vary several hundred degrees.

In addition to maintaining constant pressure, Belleville washers provide a much greater bearing area than flat washers. This is important as concentrations of stress that may cause creep are avoided.

When installing bolts and washers, it is recommended that washers be compressed to their flattened position and then the nuts backed off a sufficient amount to equal the calculated expansion variation. Utilizing this practice, optimum results are assured because the washer has become firmly seated on the bus and is exerting a force close to its maximum capacity.

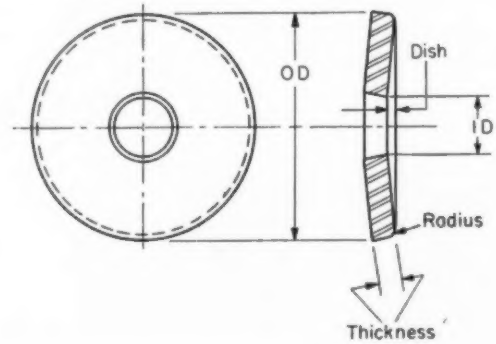
Shown in *Fig.* 3 is a typical curve for the spring listed under ½-inch bolt size in *Table* 1.

Alloy steel, chrome-vanadium AISI 6150, is recommended for application involving elevated temperature conditions while carbon spring steel, C1095, will suffice for all others except special applications at locations requiring the use of stainless steel, phosphor bronze,

Table 1—Characteristics of Typical Belleville Spring Washers*

Bolt Size (in.)	OD (in.)	ID (in.)	Thickness (in.)	Dish (in.)	Net Weight (lb)	Approx. Capacity (lb)
3/8	1 3/16	13/32	0.119	0.014	0.023	3,000
½	1 5/8	17/32	0.156	0.022	0.062	6,000
5/8	2 3/8	11/16	0.219	0.026	0.250	9,000
¾	3 ½	13/16	0.312	0.034	0.810	16,000
1	4	1 1/16	0.312	0.060	1.050	21,000
1 1/8	4	1 3/16	0.312	0.070	1.030	30,000
1 ¼	4	1 5/16	0.312	0.070	1.000	30,000

*AISI 6150 chrome-vanadium steel, heat treated.



and other special alloys.

It is very important that steel washers be protectively coated to prevent corrosion. Specification for coatings may include black oxides, electrogalvanizing, cadmium plating, phosphate coating, and aluminizing. Hot galvanizing may be used on certain designs.

From "Belleville Spring Washers" in Industrial Fasteners Institute Fasteners, *Volume* 9, *No.* 5.

Now...load rate your bearings at higher values

with **Tru-Rol** CROWNED ROLLERS

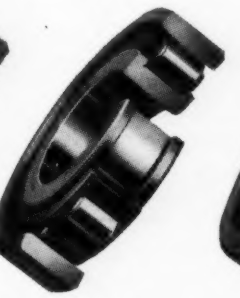
Greater capacity . . . longer life . . . or a precisely balanced gain of *both* factors. That is the choice offered you by the "crowned" rollers of Tru-Rol bearings.

By finish grinding a carefully selected crown radius on roller ends, Rollway relieves high stress areas, insures uniform distribution of load over the entire length of the roller. Rollers can take heavier loads without excessive end-fatigue, and are less subject to the effect of slight misalignment or deflection.

The result is load rating at higher values for greater capacity, longer service life . . . or both. If this choice interests you, why not write for the complete story. Rollway Bearing Co., Inc., Syracuse, N. Y.

Tru-Rol Bearings with crowned rollers are available in 3 types

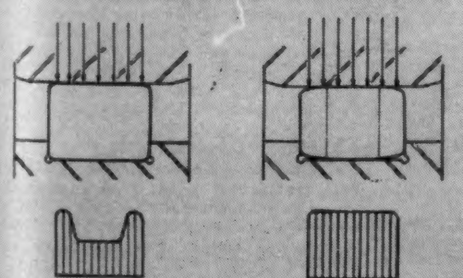
Stamped Steel Retainer with Guide Lips



Segmented Steel Retainer

Full Roller

Comparative Stress Patterns under Uniform Loads for Straight and Crowned Cylindrical Rollers



Stress pattern for a straight cylindrical roller under load. Note uneven end-loading.

Stress pattern for crowned roller under load. Crowning radius is exaggerated for clarity.

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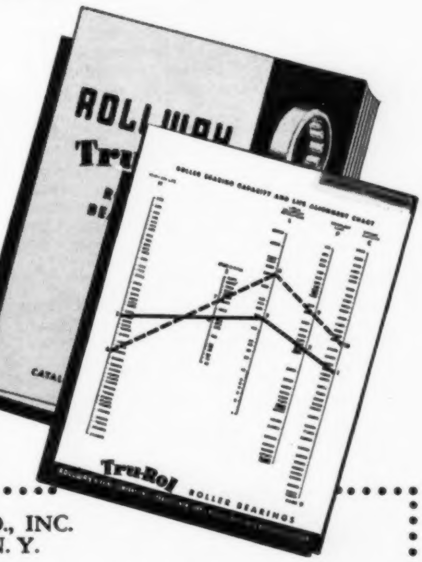
*Roller Bearing Engineers' Comm. — Anti-Friction Bearing Mfrs. Assn.



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ENGINEERING OFFICES: Syracuse • Boston • Chicago • Detroit • Toronto • Pittsburgh • Cleveland • Milwaukee • Seattle • Houston • Philadelphia • Los Angeles • San Francisco

Helpful Literature

(*Continued from Page 254*)

6-page illustrated folder. Also detailed are six plug-in preamplifiers, single-channel recorder and four-channel system for use with analog computers.

38. Fabrication Facilities

Plume & Atwood Mfg. Co.—Stamping, drawing, forming and heading facilities of this company are described in 12-page catalog. It shows how by combining operations several items are now produced at substantial savings.

39. Teflon Rods

Garlock Packing Co.—Physical properties of two grades of Teflon available in rod form to fabricators of finished Teflon parts are found in 4-page bulletin AD-149. One grade is made from virgin Teflon powder, the other from reprocessed Teflon. Typical uses are outlined.

40. Oil Industry Pumps

Viking Pump Co.—Positive-displacement rotary type Viking pumps which are specifically designed for oil industry application are subject of 14-page illustrated catalog section G. Rated 35, 50, 90, 150, 200 and 300-gpm per unit, pumps are designed for 50 to 200-psi service. Details are given on standard and All Weather twin and multiple units, as well as on truck mounting pumps.

41. Socket Screws

Bristol Co.—Features, manufacturing methods and applications of line of socket screws are covered in two bulletins. Tables of nominal sizes, basic dimensions and tolerances of American Standards for screw threads, plus engineering data and application information are included in the 20-page illustrated bulletins. No. 898 covers hex type and No. 899 covers multiple spline type socket screws.

42. Plastic Pipe & Fittings

Alpha Plastics, Inc.—How to use and specify rigid plastic pipe and fittings is subject of 12-page catalog. Data on ½ to 4-in. line of normal and high impact unplasticized polyvinyl chloride pipe and fittings are included, along with properties and characteristics, detailed drawings and specifications.

43. Resistance Units

Helipot Corp.—Series T-10-A precision variable resistance units for instantaneous setting are subject of data sheet. Designed for use as potentiometers or rheostats in experimental circuits, they have their specifications given.

44. Double Helical Gears

Worthington Corp.—Specifications, construction, design, testing and various applications of double helical gears are covered in 12-page illustrated bulletin 1958E. It also contains data on lubrication, diagrams and application charts listing dimensions.

45. Rotary Sanitary Pumps

Viking Pump Co.—14-page illustrated catalog section F deals with line of sanitary pumps in rated capacities of 20, 35, 50 and 90 gpm at pressures to 50 psi. At reduced speeds, pumps will handle fluids with viscosities up to 10,000 S.S.U. Described are various types of drives including, geared, straight-line, belt, variable speed and integral. Pumps meet 3A sanitary specifications.

46. Retaining Rings

Waldes Kohinoor, Inc.—Two pages in supplement No. 1 to Truarc retaining ring catalog RR 9-52 are devoted to engineering data and specifications covering use of two internal and two external rings in deeper grooves than those specified in the catalog. Design change makes possible an increase in thrust load and impact capacity. New specifications for other rings are also covered.

47. Magnet Wire Data

Anaconda Wire & Cable Co.—84-page catalog section 12 is latest revision of data on magnet wire. Section is designed as replacement in the Company's general catalog and is also available separately. Up-to-date information is given on high-temperature wire insulations, aluminum wire, square and rectangular wire and complete line of round magnet wire. Engineering, design and application data are combined in one reference section.

48. Stainless Tubing & Pipe

Carpenter Steel Co.—Carpenter 7 Mo stainless steel tubing and pipe, which combines resistance to general corrosion and stress corrosion cracking, is described in 4-page illustrated bulletin T.D. 116. Analysis, physical characteristics and mechanical properties are presented and hot and cold working instructions are given.

49. Steel Tubing

Higbie Mfg. Co., Avon Tube Div.—Fusion-weld thin wall steel tubing, made by a high cycle, electric resistance welding method, is described and illustrated and its specifications given in 8-page bulletin. It is made in sizes from ⅛ to ¾-in. with wall sizes up to 0.049-in. and in as-welded, hard drawn and soft annealed grades. Fabrication data, properties and applications are covered.

50. Motor Buying Information

General Electric Co.—28-page catalog of buying information on alternating current motors is designated GEC-1026. Both fractional and integral horsepower motors are detailed, including general and definite-purpose types as well as fractional horsepower gearmotors. Specifications are given for single-phase, polyphase, totally-enclosed fan-cooled and gear type integral horsepower motors.

51. Zinc Phosphate Coatings

Oakite Products, Inc.—"How to Apply Zinc Phosphate Coatings to Steel in Preparation for Painting" is title of 10-page illustrated guidebook F.8979R. Materials used in the CrysCoat process to provide paint-anchoring corrosion-resistant coatings are described. Procedure is outlined.

52. Valves

Barksdale Valves—Comic-strip technique is employed to explain the Shear-Seal principle employed in line of quarter-turn control valves for hydraulic applications. Included in pocket of explanatory booklet is a cut-out working model and cross - section which dramatizes the functioning of these valves.

53. Hard Surfacing Alloys

Coast Metals, Inc.—Engineering data on No. 18 and No. 118 hard surfacing metals for improving the wear, abrasion and shock resistance of metal parts are presented in 4-page illustrated bulletin. Included are information to aid in the welding and finishing of these materials.

54. Stainless Steel Gate Valves

Cooper Alloy Foundry Co.—Alloy stainless steel gate valves in a wide variety of designs for services at pressures up to 300 psi are briefly covered in 4-page illustrated bulletin 55G. Table of alloy designations is guide to type of fluids which can be handled with various alloys.

55. Industrial Glassware

Corning Glass Works—Composition, manufacture and application of Vycor brand 96 per cent silica glasses are subject of 8-page illustrated bulletin B-91. Material can be heated to 900° C and plunged into ice water without breaking. In addition to extreme resistance to thermal shock, glasses have exceptional chemical stability and high transmission of ultraviolet and infrared bands of the spectrum.

56. Paper Temperature Indicators

Paper Thermometer Co.—6-page folder is descriptive of line of Thermopaper temperature indicators which are extremely accurate. Various units are available in stock for specific temperatures in range from 113 to 490° F. Strip of black paper imprinted in white with indicated temperature in heat-sensitive ink is placed on test surface. White letters turn black and disappear when object temperature reaches indicator temperature. Action is not reversible. Successively higher temperature indicating papers can be used to determine exact temperatures.

57. Sea Water Condensers

Halstead & Mitchell—Details of cleanable double-tube counterflow sea water condensers for marine and naval service are given in 2-page illustrated bulletin C-4. These units provide up to 50 per cent more heat transfer surface than is found in standard fresh-water condensers.

58. O-Rings

Garlock Packing Co.—Design information, recommended and available materials for both "dynamic" and "static" applications of O-rings are presented in this 16-page illustrated catalog AD-148. List of standard stocked O-ring sizes is included.

59. Lead-Bearing Steel Data

Peter A. Frasse & Co.—Engineering memorandum No. 12 contains useful information on analysis, typical mechanical properties and machining comparisons for Ledloy-A free-machining lead-bearing steel. Why this material can be used economically for many applications is explained.

60. Speed Reducers

Winsmith, Inc.—Advantages claimed for the recently announced C Line worm gear speed reducers are clearly pointed out in 8-page illustrated catalog CHW-654. These compact units are available in worm on top, worm on bottom and vertical designs. Five sizes cover range of 1/100 to 5 hp in a ratio range of 5:1 to 77:1.

61. High Frequency Insulators

American Lava Corp.—16-page illustrated bulletin 546 is entitled "AlSiMag L-5 High Frequency Electrical Insulators." All requirements for JAN-1-8 type insulators can be filled with stock items from this catalog from one source. Descriptions of available stock insulators, dimensions and properties of various ceramics are listed.

62. Air-Hydraulic Pump

Powermatic Sales Co.—Design, operating and application information on Powermatic pumps which convert high-volume low-pressure air into low-volume high-pressure hydraulic power are contained in 4-page illustrated bulletin. Pumps are offered with air-to-hydraulic pressure ratios of 130:1 to 16:1 which deliver hydraulic pressures as high as 18,850 psi.

63. Motor Controls

Furnas Electric Co.—Vest-pocket catalog No. 5411 contains 46 pages of design and application data on magnetic starters and contactors; push buttons; combination starters; drum controllers and master, foot, limit and pressure switches.

64. T-Slot Bolts

Standard Parts Co.—Entitled "Tooling for Competition," 2-page bulletin shows construction of Standard T-slot bolts which are forged from 200,000-psi tensile strength alloy. Lengths range from 2 to 12 in. in ½, ⅝ and ¾-in. diameters.

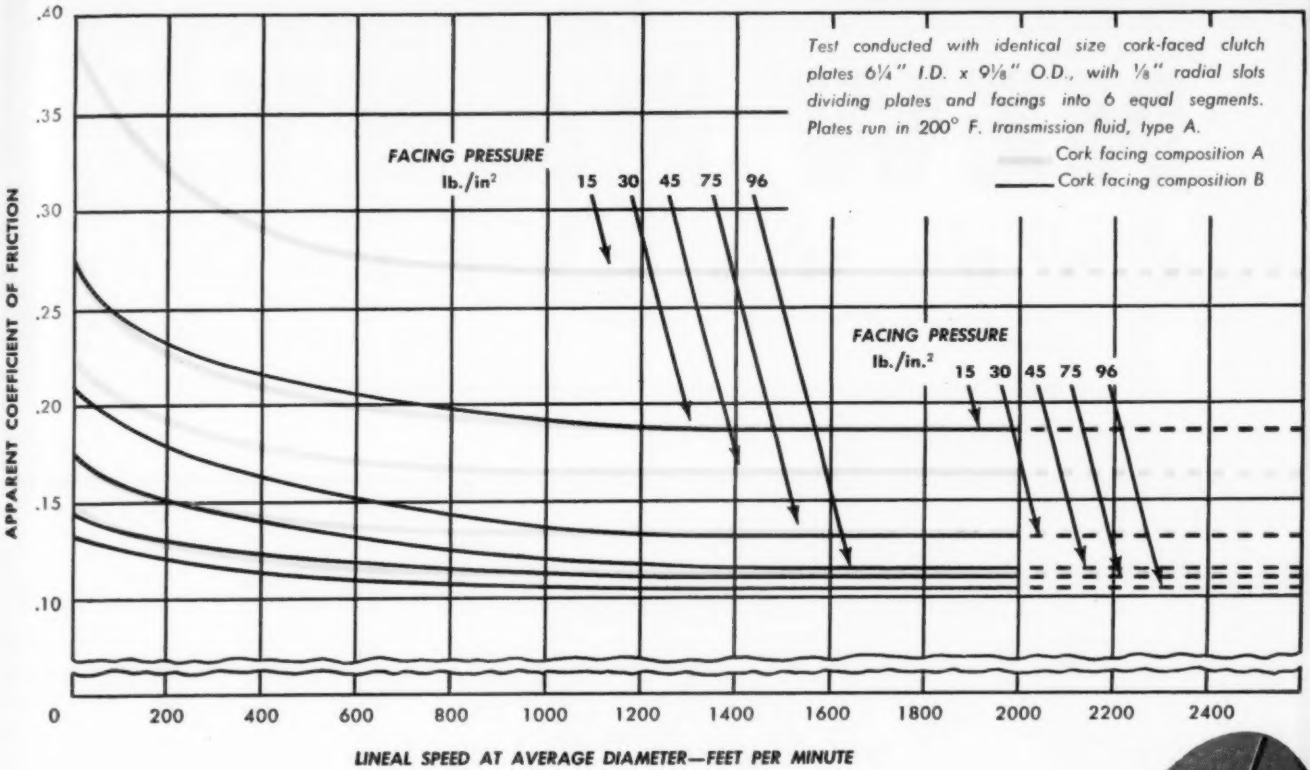
65. Electrical Insulation

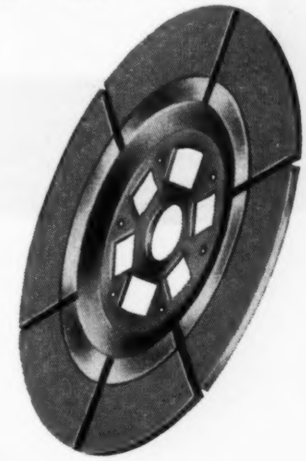
Formica Co.—Single page data sheet describes grade Q-125 laminated paper-base material which has excellent arc resistance and fire quenching properties. Designed for use in electronic equipment, this insulating material is available in thicknesses from 1/32 to 1 in.

66. Vibration Isolators

Barry Corp. — Construction details, load ranges, applications and vibration characteristics of series M24 miniature All-Metl vibration isolators are found in 8-page illustrated bulletin 542. Four styles are available.

THE EFFECT OF CHANGES IN CORK COMPOSITION





CORK CLUTCH FACINGS:

How torque capacity can be modified by changes in cork composition

Cork-compound friction materials as a class have unusually high torque capacity. Equally important to designers, however, is the fact that this capacity can be widely modified by changes in the cork composition.

Cork clutch facings can be compounded with a variety of resins, fibers, and rubbers. As a result, there is a wide range of cork compounds available, each offering somewhat different torque capacity. Within this range, designers can usually find a facing material that will deliver the exact performance required.

The chart above illustrates how changes in clutch capacity can be produced by modification of the cork compound used as facing. The values shown were developed by clutch plates identical in all respects except for the facing compound. The frictional patterns of both are similar, because the metal plates were of the same design and size. But the apparent coefficients of friction produced by composition A are higher than those produced by composition B.

This wide range of torque capacities is only one of many unique advantages which cork-compound friction materials offer. For more information on the performance versatility of these materials, send for a copy of our new booklet, "Armstrong Resilient Friction Materials." Write on your letterhead to Armstrong Cork Co., Industrial Div., 7205 Dean Street, Lancaster, Pennsylvania.

Armstrong FRICTION MATERIALS

. . . used wherever performance counts

NEW PARTS
AND MATERIALS

For additional information on these new developments, see Page 253

Instrument Bearings

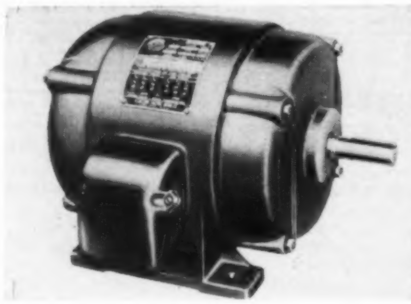
Bore sizes offered in line of thin-section instrument bearings range from 0.6250 to 3.1245 in. The high load capacity, long life bearings have one-piece synthetic retainers, full ball complement, alternate undersize ball complement, or either of the latter two with integral shielding. Alternate ball series has slightly undersize alternate balls

which act as spacers, providing the bearings with low and constant torque values at low and moderate speeds. Made by **Split Ballbearing Corp.,** Lebanon, N. H.

For more data circle MD-67, Page 253

Electric Motors

Small frame industrial ac motors, built to NEMA standards, incorporate low air opening in end bell combined with a steel baffle plate to protect winding from moisture and abrasive dusts in the dripproof design. Double-end ventilation is provided by dual cast aluminum fans. Motors use double-width prelubricated sealed ball bearings. All standard ratings are

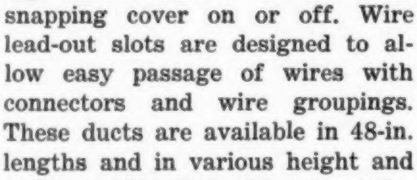


availble in frame sizes 182, 184, 213 and 215. Models up to 30 hp will be available. Made by **Lima Electric Motor Co.,** 117 Findlay Rd., Lima, O.

For more data circle MD-68, Page 253

Wiring Duct

Style XT Panel-Chanel consists of laminated phenolic resin, one-piece, U-shaped channel and extruded, high-impact polystyrene cover. Attachment or removal of cover is accomplished by compressing flexible sides of channel and snapping cover on or off. Wire lead-out slots are designed to allow easy passage of wires with connectors and wire groupings. These ducts are available in 48-in. lengths and in various height and width combinations from 1 x 1 in.

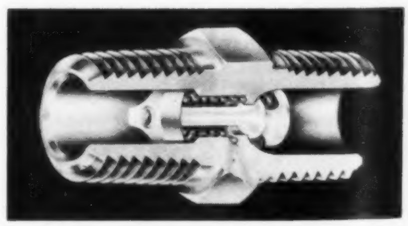


to 3 x 3 in. Made by **Stahlin Bros. Fibre Works Inc.,** Belding, Mich.

For more data circle MD-69, Page 253

Check Valve

Circle Seal 2300 series check valve is suitable for use at pressures to 10,000 psi. Of floating poppet design, it is not affected by foreign particles in the fluid and eliminates wire drawing across the seat. The valve's spherical metal seat assures correct seating and support for the O-ring, which serves as a sealing member and absorbs the closing shock. Suitable for most high-pressure hydraulic or



pneumatic applications, the valve is available in several combinations of body and O-ring materials. Made by **James-Pond-Clark,** 2181 E. Foothill Blvd., Pasadena 8, Calif.

For more data circle MD-70, Page 253

Wing Nuts

High Wing and Low Wing nuts can be employed where lack of sufficient overhead or side space prohibits use of standard wing nuts. The low wing type has a lower-than-normal wing height and wider-than-normal wing spread. The high wing nut has a narrow, higher-than-average wing spread. Both types are offered for special needs and have GRC Finger-Grip recessed wings and clean threads. They are

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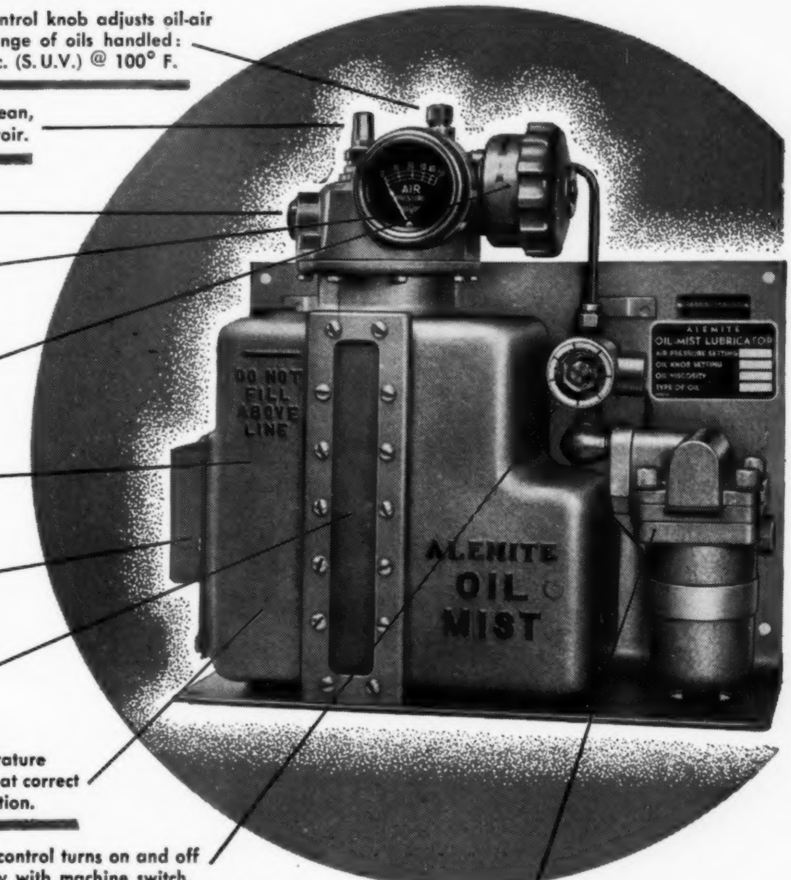
ALEMITE **OIL-MIST**

Proved in countless applications—multiplies bearing life—slashes product spoilage—boosts machine output!

Hundreds of case histories prove savings, ease of installation, increased output with Oil-Mist. And Oil-Mist is simple to design into any machine. Oil-Mist applies a constant, clean, cool film of oil uniformly to working parts — vees, chains, slides, gears, all types of bearings. Replaces grease systems. No moving parts — operates on compressed air — completely automatic, fool-proof!



1. Oil flow control knob adjusts oil-air mixture. Range of oils handled: to 1,000 sec. (S.U.V.) @ 100° F.

2. Loader fitting for fast, clean, filtered refilling of reservoir.

3. Oil-Mist delivery outlet for main line leading to bearings.

4. Air gauge registers to 50 psi.

5. Air regulator—operating pressure 5 to 20 psi. Reduces pressures from up to 200 psi. Normal air consumption, .7 to 1.2 cfm.

6. Reservoir capacity one gallon. Also available in 12 oz. size.

7. Low level indicator switch turns on warning signal or stops the machine when oil level is low.

8. Nylon plastic window gives visible check of oil supply.

9. Heater for outdoor or low temperature applications. Thermostat keeps oil at correct temperature for efficient atomization.

10. Solenoid air control turns on and off simultaneously with machine switch.

11. Moisture separator and filter removes up to 98% of moisture from incoming air at flow rate up to 1 cfm.

Complete range of models and multiple unit models to fit any machine—any application

Three types of bearing fittings allow the use of OIL-MIST on any machine!

Oil-Mist fittings bring the most efficient lubrication in the world to any anti-friction bearing—roller, ball, needle.

Spray fittings are recommended for open and enclosed gears and chains. Allow for a concentrated spray of oil where needed.

Condensing fittings apply oil in liquid form to plain bearings, slides, ways, vees, cams and rollers.

Alemite Oil-Mist offers these lubrication advantages

Automatic lubrication • Continuous lubrication
Eliminates guesswork • Greater safety • Cuts oil consumption up to 90%
Extends bearing life • Stops oil drippage • Saves man-power
Reduces number of lubricants needed • Eliminates "Down-time"

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ALEMITE **OIL-MIST** LUBRICATION

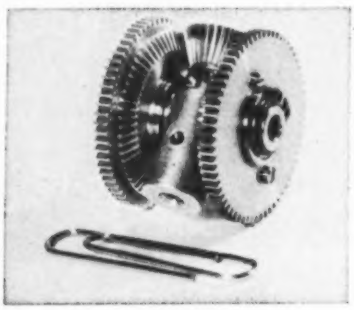
A PRODUCT OF SW STEWART WARNER

cast of nonferrous, corrosion-resistant zinc alloy and offered in all commercial finishes, if desired. Made by **Gries Reproducer Corp.**, 400 Beachwood Ave., New Rochelle, N. Y.

For more data circle MD-71, Page 253

Differential Gear Unit

Hollow shaft type miniature differential gear unit is supplied completely assembled for easy mounting at any position on a shaft. It is usable in servo systems, missile navigational systems and related

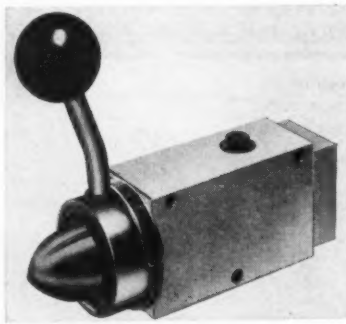


equipment. Models for $\frac{1}{8}$ or 3/16-in. shafts have overall length of 0.930-in. Backlash is less than 7 minutes (3-minute backlash can be specified) and break-away torque is less than 0.01-oz-in. Spur gears of either 48, 64, 96 or 120-pitch can be used on the ends. Of stainless steel construction, it has shielded type stainless steel bearings. Made by **Reeves Instrument Corp.**, 215 E. 91st St., New York 28, N. Y.

For more data circle MD-72, Page 253

Flow Regulator

Model 1407-4 adjustable flow regulator is suitable for a system which requires variable adjustment of flow rate over a wide operating range. Designed for flow requirements between 0.5 and 20 gpm, the regulator maintains a constant rate of flow at any position of the control handle, regardless of variations in pressure or back pressure. Minimum to maximum flow adjustment is obtained by 180-deg handle rotation. Flow rate changes can be made under any condition of pressure or back pressure. Right and/or left-hand rotation of control handle is available; thus an

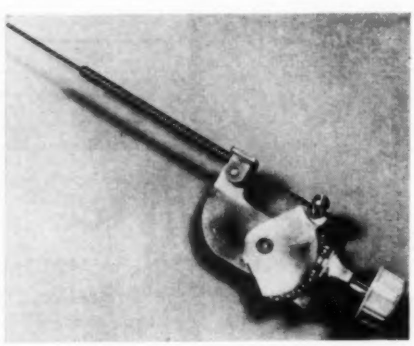


operator can control two operations simultaneously. Regulator operates at 3000 psi. It has an aluminum body and steel working parts. Weight is about 4.5 lb. Made by **Waterman Engineering Co.**, 725 Custer Ave., Evanston, Ill.

For more data circle MD-73, Page 253

Remote Control

This sector gear and pinion device, together with wire type flexible control is designed for remote operation of auto heater vents and valves, dampers on air conditioning units and similar applications. It will produce $1\frac{1}{2}$ in. of linear push-pull motion when knob is turned 270 degrees. External portion occupies $1\frac{3}{4}$ x $1\frac{1}{4}$ in. of panel area with $2\frac{1}{2}$-in. clearance behind panel. One nut is required for mounting. Device is constructed of plated steel, and operation is un-



affected by dust or grit. Made by **Arens Controls Inc.**, 2017 Greenleaf St., Evanston, Ill.

For more data circle MD-74, Page 253

Mercury-Vapor Thyratron

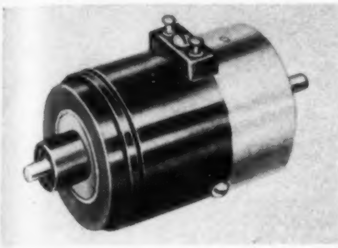
Model 5563-A high - voltage, three-electrode, mercury-vapor thyratron has a negative control characteristic. Designed primarily for power-control applications, it is also suitable for use in load-circuit protection. In power-control applications, the tube is operated so that its dc output voltage to the load is varied by varying the time of firing during the ac input cycle. Three tubes used in this manner in a half-wave, three-phase circuit handle up to 45 kw at a dc output voltage up to about 9500 v; six tubes in a series, three-phase circuit can handle up to 143 kw at a dc output voltage up to about 19,000 v. For protection applications, the tube can be operated as

a grid-controlled rectifier to remove the dc load voltage by blocking action of the grid, or as an electronic switch across the rectifier output to remove instantaneously the load voltage in case of a fault in the load. Tube is $2\frac{7}{8}$ in. in diameter, 10 3/32 in. long and has a 4-pin bayonet base. Made by **Radio Corp. of America**, Tube Div., Harrison, N. J.

For more data circle MD-75, Page 253

Clutches, Clutch Brakes

Precision miniature clutches or clutch brakes are designed for use in electromechanical control systems, servomechanisms and other devices, and for such functions as



rapid starting and stopping, rapid positioning, tuning and cycling, speed controlling and synchronizing of shafts. Units operate on the principle of an electromagnetic actuation of a friction plate to provide virtually instantaneous starts and stops. Energizing the coil engages the clutch and provides instantaneous power pick-up; de-energizing the coil disengages the clutch and braking action occurs, if desired. Energizing or de-energizing can be controlled remotely by vacuum tubes, limit switches, relays or other devices. Standard coil voltage is 28 v dc; coil voltage and current can be provided to meet requirements. Units have through output shafts, which permits input and output on the same end. Made by **Globe Industries Inc.**, 1784 Stanley Ave., Dayton 4, O.

For more data circle MD-76, Page 253

Magnetic Amplifier

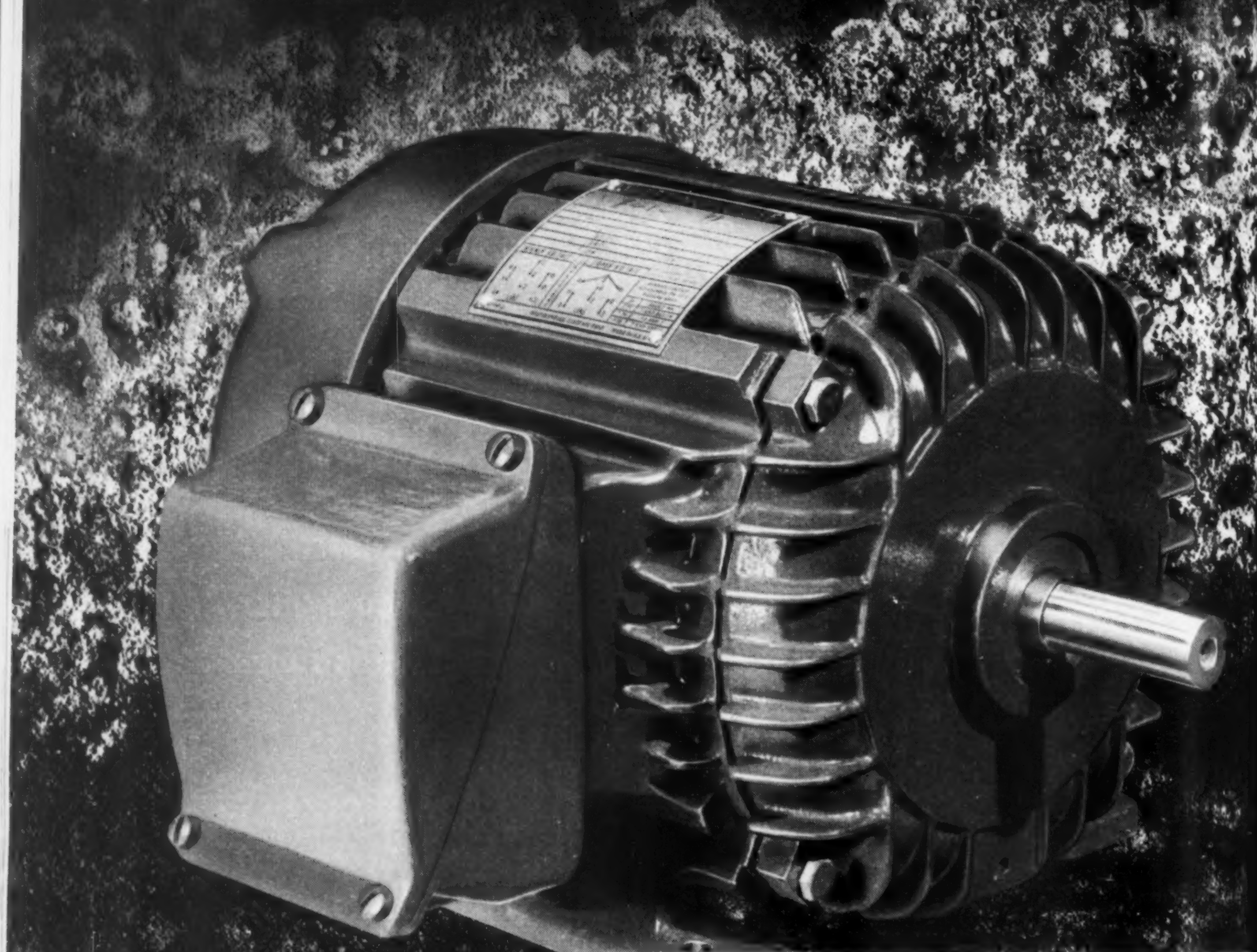
Model 505-1 constrained bridge magnetic amplifier has high power efficiency and very low quiescent power consumption and is free from zero drift due to change in

rectifier characteristics. Suitable for the control of large power devices requiring efficiency and stand-by power, it is also applicable to instrument servo applica-

(*Continued on Page* **266**)

MOTOR FACTS ON INDUSTRY'S

MOST PREFERRED "POWER PACKAGE"



Electrical System Fact—Only the new Life-Line "A" motor gives you the unsurpassed corrosion-resistant protection of exclusive new Bondar, Bondite and Mylar* insulations.

*Du Pont Registered Trade-Mark

New Parts

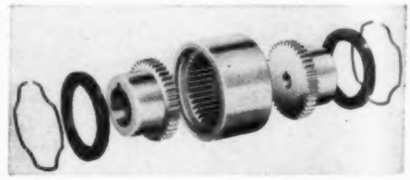
(*Continued from Page* 263)

tions in which close packaging requires minimum size and where force cooling is not possible. Efficiencies up to 90 per cent are possible for response lags of a few cycles of the power frequency. Amplifier operates on 115 v, 400 cycles ac; power consumption for full output is 3.5 w. Input impedance is 10,000 ohms. Made by **Librascope Inc.,** 808 Western Ave., Glendale, Calif.

For more data circle MD-77, Page 253

Flexible Coupling

Medium Duty flexible gear coupling is made in one size which accommodates shafts from ½ to 1¼ in. The one-piece smooth sleeve and the hubs are powdered steel, which has tensile strength of 35,000 psi. Asbestos-Neoprene seals



are resistant to heat and corrosion. Easily installed and removed spring steel snap rings withstand 50,000 lb of end thrust. Compact coupling has positive gear drive and high horsepower capacity. It operates at high speeds and can be assembled and uncoupled in seconds' time. Made by **Sier-Bath Gear & Pump Co. Inc.,** Coupling Div., 9252 Hudson Blvd., North Bergen, N. J.

For more data circle MD-78, Page 253

Speed Reducers

Models with standard extended shaft and those with worm over, under or vertical are available in Cone-Drive double-enveloping worm-gear speed reducers. Units can be ordered with or without motors, since the motor bell housing adapter will accommodate standard NEMA C-type flanged motors. Reducer is coupled to the shaft to be driven, or mounted on the shaft if a shaft-mounted model is specified. Large tapered roller

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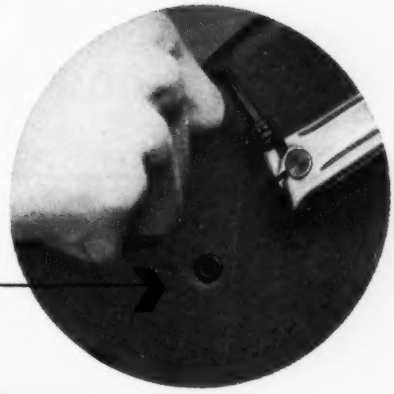

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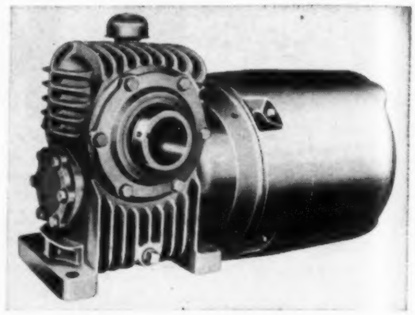
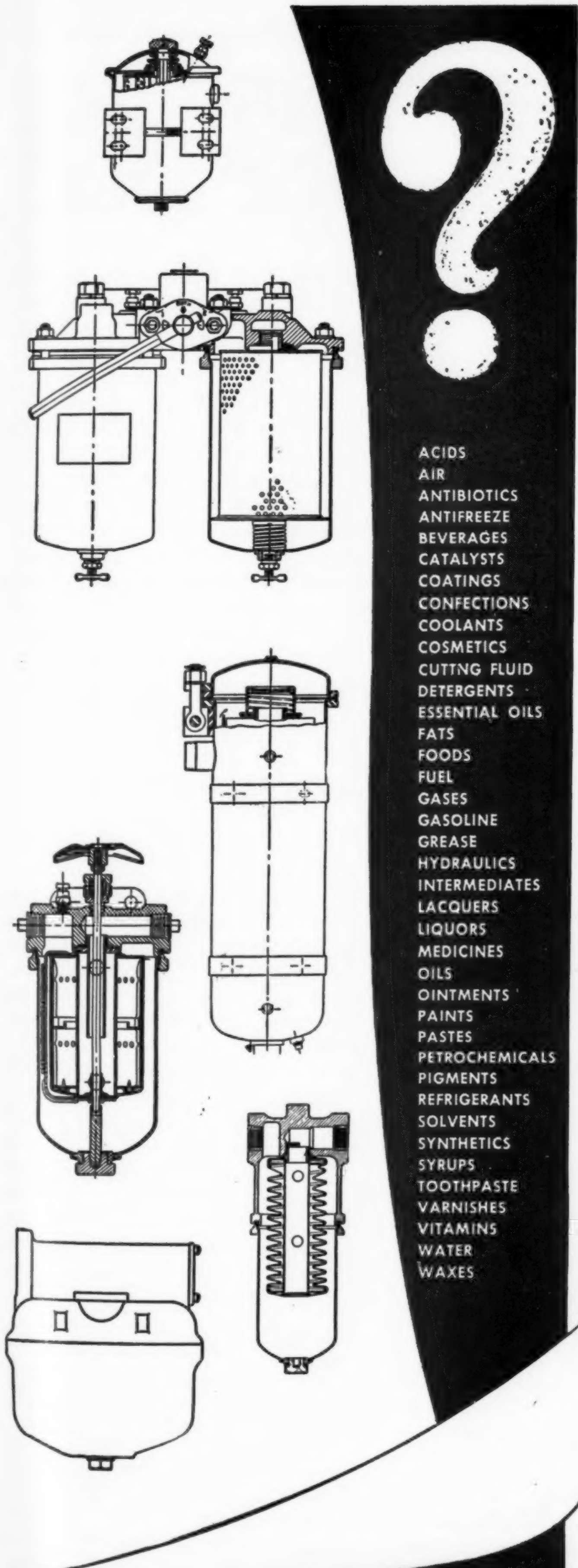


bearings on the output shaft and a heavy ribbed housing permit placing unsupported loads on the reducer in many applications. All motorized models can be wall, ceiling or floor mounted in any position. Present line includes 2, 2½ and 3-in. center distance units. Reduction ratios range from 5:1 to 60:1; load capacities, from fractional to 9 hp. Made by **Michigan Tool Co.,** Cone-Drive Gears Div., 7171 E. McNichols Rd., Detroit 12, Mich.

For more data circle MD-79, Page 253

Air Control Valves

Model 6664 air control valve, one of three new models with locking toggles, controls bleeder and pilot-operated master valves. Removal of center port plug makes the two-way valve into a three-way model. Hand operated, it will lock in the off-center (angle) position and is released manually to vertical (off) position. Locking position can be rotated 360 degrees. Similar dual-control, two-way model 6665 has two exhaust openings which permit bleeding both ends of the master valve alternately. Automatic reversal is thus provided when toggle lever is returned to normal (vertical) position. Model 6676 is a four-



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PUROLATOR

"FIRST in the field of filtering"

way, two-position valve with locking toggle lever, designed for manual control of double-acting air cylinders. It locks at off-center (angle) position to maintain position of cylinder at end of stroke. Cylinder movement is reversed by manual or automatic trip dog release. Port size of all models is ¼-in. Made by **Logansport Machine Co. Inc.**, Logansport, Ind.

For more data circle MD-80, Page 253

Air Filter

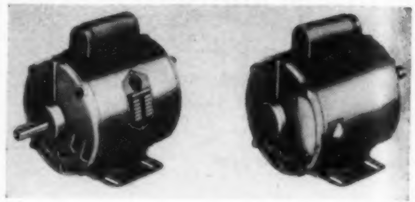
Phenolic resin impregnated cellulose cylinder, the filtering element in the model F-1 air filter, removes dirt particles as small as 40 microns on standard models or smaller on special order. Device is used

with instruments, air tools, spray painting equipment and other air-operated apparatus. Filtering element is easily removed for cleaning in almost any solvent, including kerosene or gasoline. Of all-brass construction, filter has ¼-in. NPT connections and is available with wall mounting bracket if desired. It is unaffected by oil or water accumulation. Made by **Conoflow Corp.**, 2100 Arch St., Philadelphia 3, Pa.

For more data circle MD-81, Page 253

Fractional Horsepower Motors

Conforming fully to NEMA standards for 56-frame motors, Hy-Drive fractional horsepower motors are designed for powering pumps, machine tools, farm equipment, air conditioners, industrial fans and blowers. They have ribbed base,



11-gage steel frame, cast iron end shields, Mylar insulation and improved ventilating design. Motors are available in split-phase, capacitor-start and polyphase types in ¼ to 1-hp ratings. Mechanical styles include dripproof designs with ball and sleeve bearings and rigid, resilient or face mountings; totally-enclosed ball bearing rigid mounted types; and face-mounted ball bearing units, either dripproof or totally-enclosed and suitable for vertical or horizontal installation. Made by **Hoover Co.**, Electric Motor Div., 68 Brook Ave., North Plainfield, N. J.

For more data circle MD-82, Page 253

Cartridge Roller Bearing

Self-contained cartridge roller bearing consists of outer race, roller assembly, retaining disk and seal. Presently available are bearings to fit ½ to 1⅝-in. shafts and 1⅛ to 2½-in. housing bores. Assemblies have either a type N bearing with hardened but unground rollers, for use on shafts of minimum Rockwell C-54, or type UN bearing with either unhardened and unground rollers, for use on unhardened shafts, or with hardened and ground rollers. These assemblies are made up of solid cylindrical rollers aligned and supported by rigid cage construction. To meet specific load and housing

requirements, various sized roller assemblies can be interchanged without altering the outside diameters of the outer race. Bearing is

available with or without a lubrication hole in the outer race, and with retainer disks or seals on either end or both ends. Outer race of bearing, formed from steel tubing, is continuous for high load carrying capacity. Each edge of the race is flanged to secure the seal and retaining disk. Made by **Rollway Bearing Co.,** 541 Seymour St., Syracuse, N. Y.

For more data circle MD-83, Page 253

Mercury Relay

The ten guide points are part of the one-piece drawn solenoid core shell of this mercury-to-mercury contact, double-flow type relay. This design assures long operating life. The relays are made in single

or multiple units with capacities of 10, 30 and 60 amp in single units. Time delays are available to specifications from 0.15 to 20 seconds. Normally open or normally closed contacts are available in quick-operate, quick-release; quick-operate, slow-release; slow-operate, quick release; and slow-operate, slow-release combinations. Made by **Durakool Inc.,** 1010 N. Main St., Elkhart, Ind.

For more data circle MD-84, Page 253

Toggle Valves

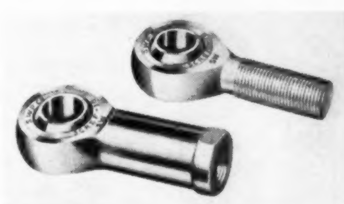
Hardened steel cams in these toggle valves provide seat closing action tight enough for high-vacuum service. Leakage during opening and closing does not exceed 0.01-micron liter per cycle. Valves range in size from 1/8 to 1/2-in.; maximum operating pressure is 1000 psi. Bodies of the valves are machined from bar stock; valve seats are semihard, corrosion resistant plastic. Brass valves have O-ring seals. Stainless steel valves are available with either O-rings or Teflon chevron packing to resist

corrosion. An adjustable cap nut permits tight seating closure when the operating lever is at right angles to the stem. Direct panel mounting is possible without modification. Made by **Hoke Inc.,** 191 S. Dean St., Englewood, N. J.

For more data circle MD-85, Page 253

Rod End Bearings

Self-aligning Scref female and Screm male spherical rod end bearings serve to minimize lost motion in linkages and withstand extreme vibration. They carry heavy loads because of their great surface supporting area. Bearings are made of one-piece ball and one-piece race,



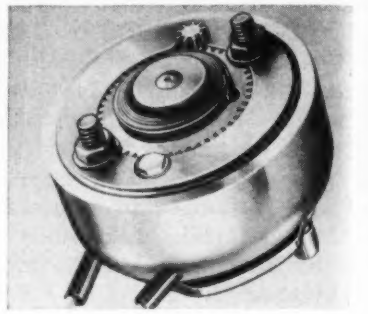
and in bore sizes from 3/16 to 3/4-in. and larger with capacities of radial ultimate loads from 1670 to 15,600 lb and higher. Available from **Southwest Products Sales Corp.,** 1707 S. Mountain Ave., Duarte, Calif.

For more data circle MD-86, Page 253

Adjustable-Spring Solenoid

Adjustable torsion springs for the Ledex BD5S and BD5E rotary solenoids are available for applications requiring close tolerance on

New Parts

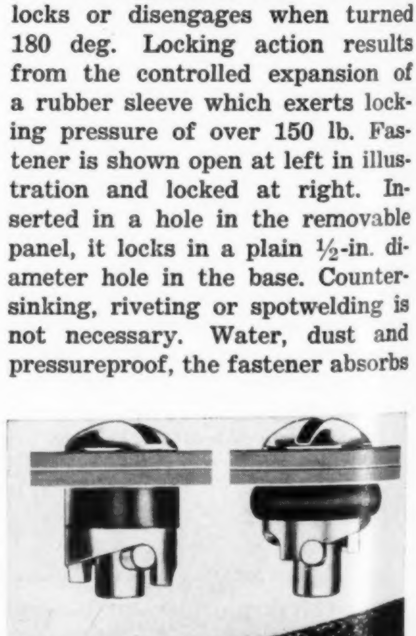


the return spring settings. Close settings are obtained by means of a vernier type adjustable spring anchor plate. Gear teeth stamped on the circumference of the anchor plate mesh with a small pinion gear. Rotating the pinion gear with the small wrench which is furnished drives the anchor plate and return spring to a precise adjustment. When proper torsion on the return spring is obtained, setting is locked by tightening the lock screw against the anchor plate. Made by **G. H. Leland Inc.**, 123 Webster St., Dayton 3, O.

For more data circle MD-87, Page 253

Panel Fastener

Vibrex panel-to-base fastener locks or disengages when turned 180 deg. Locking action results from the controlled expansion of a rubber sleeve which exerts locking pressure of over 150 lb. Fastener is shown open at left in illustration and locked at right. Inserted in a hole in the removable panel, it locks in a plain ½-in. diameter hole in the base. Countersinking, riveting or spotwelding is not necessary. Water, dust and pressureproof, the fastener absorbs



noise and isolates vibration and shock. It also compensates for misalignment between panel and base. Fastener can be used with metals, plastics, glass, ceramic and fiber and composition board. Available from **General Tire & Rubber Co.**, Industrial Products Div., Wabash, Ind.

For more data circle MD-88, Page 253

Pulse Counter

Industrial counting and computer applications are uses of the Cyclonome pulse counter which has a counting rate of 0 to 130 counts per second at an accuracy of $\pm\frac{1}{2}$-count. It uses a six-figure Veeder-Root register driven by a stepping motor, started and stopped magnetically each half-cycle. Either dc pulses down to 3 milliseconds wide

(50 per cent "on" time minimum 130 pulses per second) or ac cycles with a minimum half-cycle of 3 milliseconds can be counted. Photoelectric sensing equipment adaptable to production and process counting can be furnished. Stepping motor is offered as a separate component, with either 1.3 or 2.5 oz-in. torque. Maximum stepping speed is 260 half-steps per second. Made by **Sigma Instruments Inc.**, 77 Pearl St., S. Braintree, Boston 85, Mass.

For more data circle MD-89, Page 253

Terminal Blocks

Combination of a Curtis **FTLP** feed-through long-pin terminal block and an RH block, both standard high-current items, results in multi-contact plug-in terminal blocks. It provides high-pressure solderless anchoring for

(*Continued on Page* 280)

(Advertisement)

Vapor Pressure Bellows Devices for Remote Control of Temperature

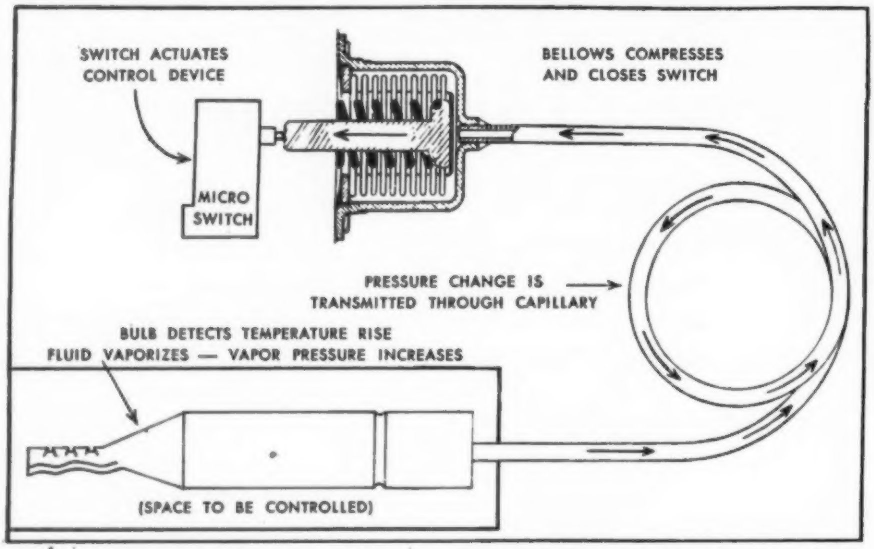


Figure 1. Vapor pressure bellows assemblies provide remote temperature control over a temperature range from about −40F to a maximum of 500F, depending on the vapor pressure of the filling medium at the maximum temperature encountered. They offer the advantage of high sensitivity and relatively long bellows stroke. This principle may be applied using increase or decrease of the vapor pressure to transmit the force to actuate a control mechanism.

ADVANTAGES OF VAPOR PRESSURE CONTROLS

Vapor pressure bellows assemblies offer a number of advantages in temperature control applications. They are highly sensitive and provide very close temperature control. They are positive-acting, simple in operation and easy to install. They can be made "fail-safe" to protect the equipment to which they are applied. When spring loaded, vapor pressure assemblies can be adjusted within very close limits. Bellows stroke is relatively long, making it easy to actuate switches or valves without elaborate linkage. They can be used for temperatures as low as −40F or as high as 500F and not affected by ambient temperatures outside of the chamber to be controlled. As a result, vapor pressure bellows assemblies are widely used as temperature controls for refrigerators, ovens, appliances, hot water storage tanks, processing equipment, wax pots, acid baths and numerous specialized industrial applications.

Proved in use. Vapor pressure bellows systems have long been used as temperature controls. Hence, a large body of performance and design data has been accumulated. This data assures accurate prediction of performance of a vapor pressure assembly, given the conditions under which the system will operate. And, since the design considerations are well known, it is usually simple to design a vapor pressure bellows assembly that will meet service requirements satisfactorily. The Clifford Manufacturing Company has a broad range of standard thermostatic assemblies engineered for quality, economy and reliable operation. These can be furnished to meet a wide variety of temperature control applications or readily adapted in design to meet special requirements. Important savings can be achieved by utilizing a standard design. A sketch showing controlling factors and dimensions for your application will enable Clifford to advise you how a standard design will meet your requirements.

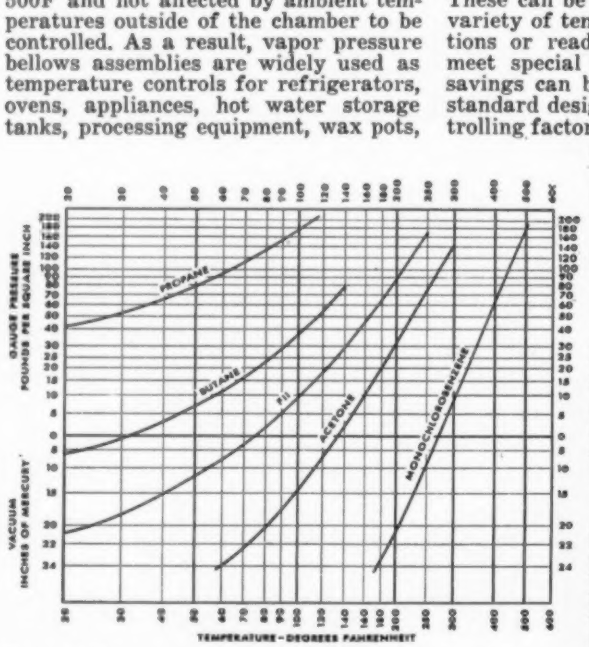


Figure 2. Vapor pressure-temperature curves for a few of the more common fluids used in vapor pressure bellows assemblies.

Operating principle (Fig. 1). When a confined liquid is heated, a vapor pressure is generated in the space above it. Vapor pressure as a function of temperature varies according to definite laws and so may be predicted accurately (see curves, Fig. 2).

Vapor pressure increases in an exponential curve. Butane, for example, from 30F to 40F changes pressure only 3 psi, but from 90F to 100F changes 9 psi. Therefore, a switch that operates with a .010 movement would have ⅓ the *temperature* differential at the higher end of the curve than a control operating at the low end of the curve.

The thermal fluid is stored in a temperature sensing bulb which is placed in the space to be controlled. The bulb is connected to a bellows cup assembly by a capillary tube. As the temperature of the bulb rises, vapor pressure in the bulb increases and is transmitted through the capillary to the cup. The force is exerted against the outside of the bellows, compressing it and moving the attached rod to actuate a switch or valve. A spring is usually incorporated as an adjusting means to provide an accurate setting of control temperature.

DESIGN CONSIDERATIONS

In the design of vapor-pressure systems, several factors must be considered: temperature range to be controlled, required sensitivity and the ambient temperature limits encountered. These requirements must be met by the right combination of bulb and bellows design and the thermal "fill" of the system.

Different combinations of factors are required if the controlled temperature is below, above, or *both* below *and* above the ambient temperature at the bellows.

Controls — bulb temperature lower than bellows. A control designed to operate at zero F, for example, must be charged with a thermal liquid having an active vapor pressure at that point, although the boiling point may be either above or below zero F. Methyl chloride (see Fig. 2) would be a logical filling medium for this application; it has a boiling point just under minus 10F and a vapor pressure of 3 to 4 psig at zero F. When used in refrigeration equipment, it functions satisfactorily, but since it has a vapor pressure of 150 psi at 120F, it would produce excessive pressure when subjected to high temperatures such as during shipment or storage of the unit. To design the assembly to withstand the overpressure would unnecessarily reduce the sensitivity of the control.

This is easily avoided in Clifford units through a calculated limited filling of the system. A volume of volatile liquid is selected so that it will be completely

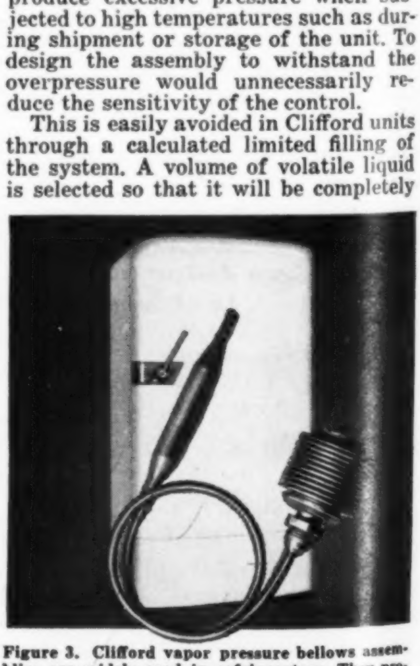


Figure 3. Clifford vapor pressure bellows assemblies are widely used in refrigerators. They provide positive action for the close temperature control essential to modern refrigeration.

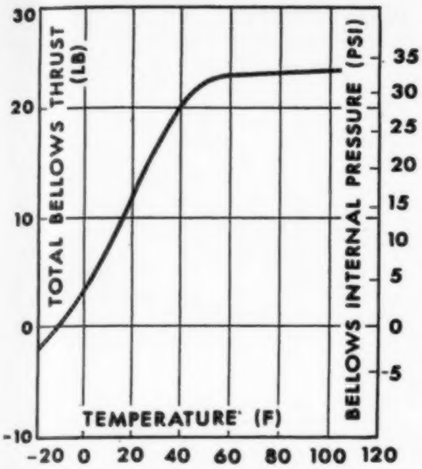


Figure 4. Temperature vs. thrust curve for a 1⅛" bellows with limited fill of methyl chloride. Full vaporization is complete about 50F. Only negligible gaseous expansion occurs above that point.

vaporized at a temperature just above the maximum desired control temperature. Beyond that point, only gaseous expansion takes place. Figure 3 shows the limited fill curve for a typical filling medium used in refrigerator temperature controls. Standard Clifford vapor pressure assemblies already engineered are obtainable for control of temperatures as low as −40F.

Ambient temperature has no significant effect on low temperature controls, because the volatile liquid is wholly contained in the bulb, which is usually quite small and located in the chamber to be controlled.

The pressure throughout the entire thermostatic assembly is always governed by the bulb temperature.

Controls—bulb temperature higher than bellows. For controls designed to operate at temperatures higher than the ambient temperature at the bellows, the assembly is almost completely filled with liquid. The vapor pressure is generated at the hottest point (the bulb) and transmitted to the bellows cup by the hydraulic action of the filling medium. The bulb is designed to trap the vapor within it, so that only *liquid* is forced out of the bulb and into the capillary and bellows cup. Over-temperature protection can be provided by limiting bulb size. Controls of this type are unaffected by ambient temperature. *The vapor pressure in the system is always a function of bulb temperature.*

Universal service. For control of temperatures *both* below *and* above the ambient temperature at the bellows, universal systems can be designed that draw on the principles of operation of both the low and the high temperature types just described. The bellows cup, capillary and bulb assembly is charged with a definite, precisely measured volume of the thermal liquid. When the capillary and bellows cup are *completely filled* with the thermal liquid, there must still be enough liquid left in the bulb to generate the necessary vapor pressure.

When the bellows and capillary temperatures go above the operating temperatures at the bulb, the liquid in the bellows and capillary vaporizes, expands into the bulb and condenses. The bellows cup is thus filled with a superheated gas at the same pressure as the vapor pressure generated by the volatile liquid in the bulb. A transition point is reached when the temperature of the bellows and capillary just equals that of the bulb. As the temperature of the bellows and capillary drops *below* that of the bulb, the liquid in the bulb rapidly vaporizes and condenses in the bellows and capillary until they are completely filled. Bulb design provides for some liquid to remain in the bulb. Further temperature increases bring about an increase in vapor pressure which is transmitted hydraulically through the capillary to the bellows cup.

Under any of the above conditions the temperature at the bulb always controls the operation of the system. The universal type control satisfies requirements that can be filled by neither the low-temperature nor high-temperature vapor-pressure types alone.

Dual Fill - Universal service can be obtained by a "dual fill" system. The unit is filled with controlled amounts of two insoluble liquids. Temperature changes are sensed by one liquid and the resulting vapor pressure changes are transmitted hydraulically through the second liquid to the bellows cup. This type of unit can be designed to have the "knock off" characteristics of the limited-fill unit (see Fig. 3).

"Fail-Safe" Design. If a liquid is chosen with a boiling point *above* the control point, the system operates under vacuum up through the control point. Vacuum should usually be limited to about 15 inches of mercury. Vacuum operation provides a "fail safe" feature in such applications as automobile thermostats. In the event that leakage occurs in the bellows or elsewhere in a closed system, the thermostat locks "open" and coolant continues to flow through the system. When controlling a heating medium, the control locks "closed" to shut off the source of the supply of heat.

Thrust. In vapor pressure assemblies, the thrust of the bellows at any temperature is definitely fixed by the vapor pressure of the filling medium and cannot be changed. Similarly, thrust differential between any two temperatures is fixed by the filling medium. Therefore, in the mechanical design of switch or valve mechanisms, friction should be minimized and maintained at a constant value.

Adjustment is commonly achieved by means of a spring and adjusting screw arrangement. The spring can control the operating temperature, the operating differential and the range over which the control temperature can be adjusted. The adjusting spring mechanism must be interrelated with the bellows cup assembly to achieve the desired operating characteristics.

Barometric compensation. For systems requiring extreme accuracy, it is sometimes desirable to compensate for barometric changes. Such correction is provided simply and accurately by a Clifford differential pressure unit (see Fig. 6). The vapor pressure is transmitted to the outside surface of the large bellows. The other side of the bellows is evacuated. The barometric changes then act on the areas of the smaller bellows, producing a null effect.

Clifford Manufacturing Company will consult with you regarding a thermostatic assembly that will meet your requirements. If you have an immediate problem, send a sketch showing controlling factors of your application and we will recommend a suitable control.

Clifford Manufacturing Company, 139 Grove Street, Waltham 54, Mass., *Division of Standard Thomson Corporation.*

Sales offices in New York, Detroit, Chicago, Los Angeles, Waltham, Mass.

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HYDRON METAL BELLOWS — CLIFFORD MANUFACTURING CO. WALTHAM, MASS. DIVISION OF STANDARD THOMSON CORP. — HEAT EXCHANGERS

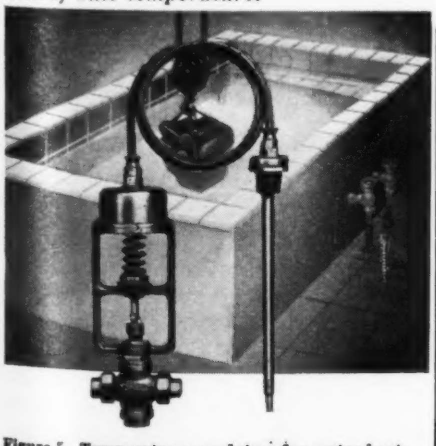


Figure 5. Temperature regulators for water heating or cooling tanks, steam cookers, acid baths, glue heaters, bottle washers, tempering baths and other heating specialties used Clifford vapor pressure bellows assemblies as actuating elements.

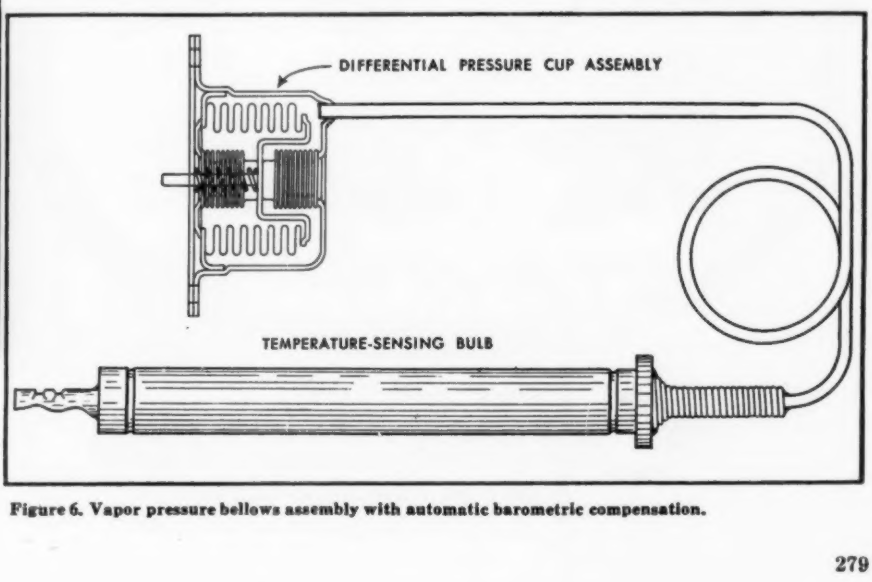
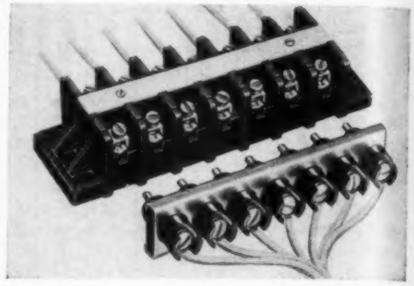


Figure 6. Vapor pressure bellows assembly with automatic barometric compensation.

New Parts

(Continued from Page 277)

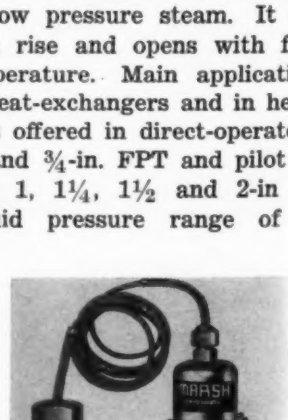


each individual connector. The FTLP blocks have ample clearance and leakage distances for use in circuits carrying up to 300 v, 20 amp. They can be specified in any number of terminals from 1 to 16. RH blocks, factory assembled with from 1 to 20 terminals, are rated at 750 v, 50 amp. Made by **Curtis Development & Mfg. Co.**, 3266 N. 33rd St., Milwaukee 16, Wis.

For more data circle MD-90, Page 253

Temperature-Actuated Valves

Two temperature-actuated valves are available in ranges of 20 to 60, 60 100, 100 to 140, 140 to 180 and 160 to 220 F. Type WT valve is designed to control flow of water, brine, oil, air or gas. It opens with rise and closes with drop in temperature. Direct-operated sizes of 3/8, 1/2 and 3/4-in. FPT and pilot-operated sizes of 1, 1 1/4, 1 1/2, 2, 2 1/2, 3 and 4 in. are made. Type HT is used to control flow of hot water or low pressure steam. It closes with rise and opens with fall in temperature. Main application is in heat-exchangers and in heating. It is offered in direct-operated 3/8, 1/2 and 3/4-in. FPT and pilot operated 1, 1 1/4, 1 1/2 and 2-in sizes. Liquid pressure range of both

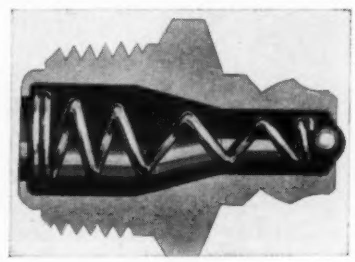


valves is 150 psi; steam pressure limit is 15 psi. Various type bulbs are available. Standard capillary tube length is 5 ft. Made by **Electrimatic Co.**, 3501 W. Howard St., Skokie, Ill.

For more data circle MD-91, Page 253

Grease Fittings

Ball-in-tip design of Surfa-Chek grease fittings keeps out dirt and other foreign matter which would damage bearings. Lubrication flows through large inner passage. A balanced-action spring retracts easily to allow maximum lubricant flow under pressure but holds ball

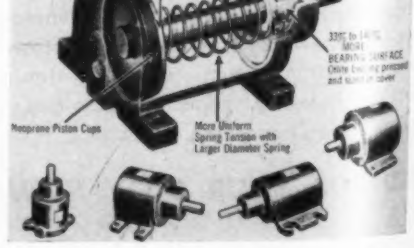


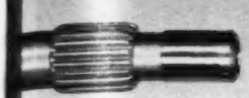
firmly in sealing position at all other times. Spherical shape of fitting base permits coupler jaws to form leakproof seal, even at a wide angle. Concave shape of head facilitates disconnection of coupler jaws. Fittings accept all standard hydraulic couplers. Made by **Aro Equipment Corp.**, Bryan, O.

For more data circle MD-92, Page 253

Air Cylinders

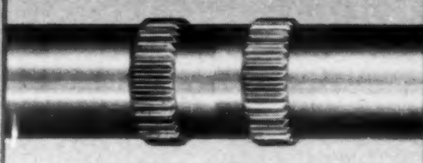
Single-acting Air-Clamp cylinders, available in 26 new models, have been redesigned with larger bearing surfaces, larger diameter return springs and Oilite ram bearings. Surfaces are machined





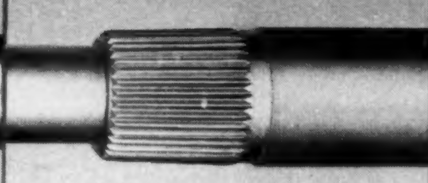
teeth
36 DP

30 deg PA
SAE 5140 H

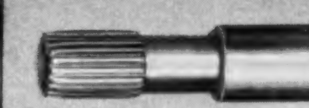


37 teeth
24/48 DP

45 deg PA
SAE 1037

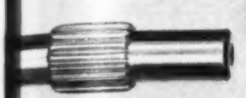


1-3/4" x 36 tapered serrations
SAE 1040



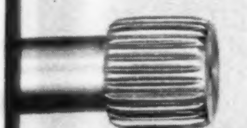
20 teeth
24/48 DP

30 deg PA
SAE 1024



eeth
6 DP

30 deg PA
410 stainless steel

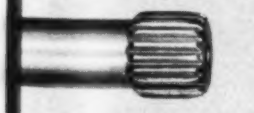


teeth
40 DP

30 deg PA
Machine steel

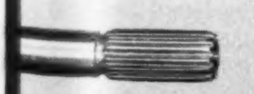
teeth
64 DP

45 deg PA
SAE 1037



teeth
/30 DP

30 deg PA
SAE 4340

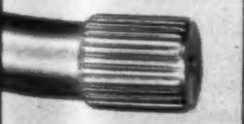


eeth
8 DP

30 deg PA
Nitralloy

teeth
36 DP

30 deg PA
SAE 1037



eeth
36 DP

30 deg PA
303 stainless steel

Announcing

NEW ROTO-FLO ROLLED SPLINES

A new "chipless" machining process, ROTO-FLO spline rolling, offers a lower-cost method to the design engineer for producing splines, serrations, and similar accurate toothed parts.

Extremely accurate, as well as low cost, the splines may be formed on a shaft, even right next to a shoulder. Helical, straight or taper splines are formed in as little as ten seconds, which is up to thirty times faster than other methods.

Shown are some of the splines that ROTO-FLO spline rollers have formed in a wide variety of metals. Fine pitch standard splines formed by this method deliver maximum torque, are easy to assemble, may even permit savings in material. Splines may be heat-treated the same as splines produced by other methods.

Request ROTO-FLO bulletin RF-54 for additional information.

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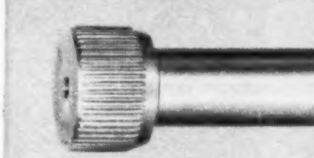
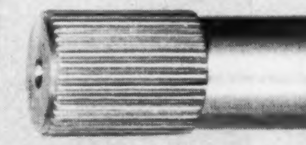


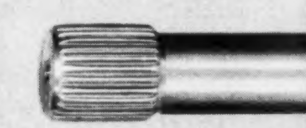
50 teeth
32/64 DP

45 deg PA
SAE 8660



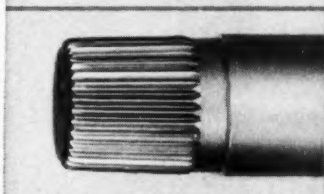
37 teeth
24/48 DP

45 deg PA
SAE 1330



28 teeth
24/48 DP

45 deg PA
ASTM-B-16 brass



1-3/4" x 36 tapered serration
SAE 1040

20 teeth
24/36 DP

30 deg PA
24S-T4 aluminum

20 teeth
24/48 DP

45 deg PA
SAE 1037

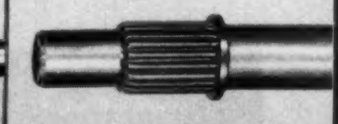
13 teeth
20/40 DP

25 deg HA
30 deg PA
SAE 1037

13 teeth
20/40 DP
25 deg HA

30 deg PA
SAE 1037

Note: Roll spline to shoulder



20 teeth
24/36 DP

30 deg PA
SAE 4130

Note: Roll spline to shoulder

where required, and tolerance, necessary to jig and fixture work, is maintained. Other improvements are use of full-floating Hycar synthetic rubber piston cups and baked-on wrinkle finish outside. Air consumption of cylinders is low. Made by **Mead Specialties Co.,** 4114 N. Knox Ave., Chicago 41, Ill.

For more data circle MD-93, Page 253

Miniature Toggle Switch

Applicable to panel mounting in test equipment, electronic apparatus, business machines and similar equipment, model A3-8 miniature toggle switch is smooth operating and has positive snap-action in either direction. Stainless steel shell affords corrosion protection

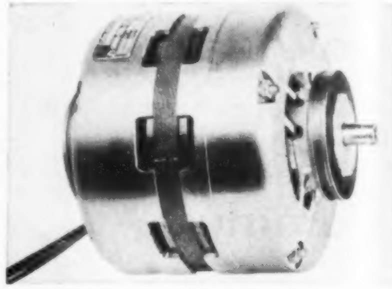
and spring mechanism is beryllium copper. Two miniature basic switches encased in the actuator provide a double-pole, double-throw circuit arrangement. Switch is ⅞-in. long and ½-in. thick. Electrical rating is 5 amp at 125 to 250 v ac; 4 amp resistive or 2.5 amp inductive at 30 v dc. Made by **Electro-Snap Switch & Mfg. Co.,** 4218 W. Lake St., Chicago 24, Ill.

For more data circle MD-94, Page 253

Induction Motor

Business and dictating machines, fascimile equipment, tape recorders and other commercial and military equipment are applications for the model D7302 induction motor, rated 1/100 to ⅛-hp. Die-cast zinc housing assures exact bearing alignment and air gap concentricity. Motor is available in 2, 4, 6, 8 and 12-pole versions, single and dual speed combinations, in stand-

New Parts

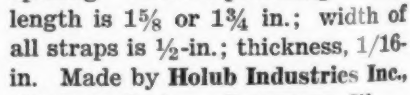


ard induction and synchronous types. It operates with low wow, flutter and external field and very low temperature rise. Magnetic circuit is well balanced, and either ball or sleeve bearings are used. Made by **Howard Industries Inc.**, 1760 State St., Racine, Wis.

For more data circle MD-95, Page 253

Plastic Straps

Corrosion resistant straps to fasten and support all types of open wires, cables and cords are made of strong, pliable, lightweight polyethylene. Unaffected by heat, cold, moisture, salt air and gaseous fumes, they will not rot, rust or corrode. Strap edges are thick and rounded for protection against



short circuits under vibration, strain or wind. Mounting holes hold screws or nails while driving. Straps are black or ivory, with 1/4 x 7/16-in. or 7/16 x 9/16-in. opening. Corresponding strap length is 1 5/8 or 1 3/4 in.; width of all straps is 1/2-in.; thickness, 1/16-in. Made by **Holub Industries Inc.**, 414 DeKalb Ave., Sycamore, Ill.

For more data circle MD-96, Page 253

Solenoid Valve

Air, various gases, water, gasoline, light fuel oil and other fluids up to 180 F can be controlled by the model 8030A direct-lift solenoid operated valve. For low-pressure operation up to 7 psi, the packless valve is available in 3/8 and 1/2-in. pipe sizes. Only moving element is a stainless steel core and com-

position disk, housed in a forged brass body. Large ports assure high rate of flow at low pressure drop. Normally closed valve requires 10 w to operate. Explosion-proof and watertight solenoid enclosures are available. Made by **Automatic Switch Co.**, 391 Lakeside Ave., Orange, N. J.

For more data circle MD-97, Page 253

Bushing

This rivet type hermetic seal bushing meets MIL-T-27 specifications and conforms to the MIL-T-27 twist test. It will not develop

cracks or leaks. Insulation resistance at 45 per cent relative humidity at sea level is over 500,000 megohms. Bushings are available in five standard styles, or they can be modified to meet requirements. Available from **Heldor Mfg. Corp.**, 238 Lewis St., Paterson, N. J.

For more data circle MD-98, Page 253

Metal Adhesive

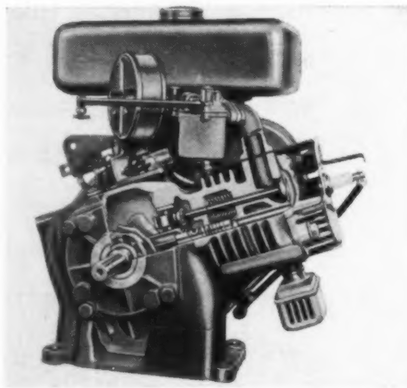
Supplied in ready-to-use paste form, R-385 bonding agent is a one-component epoxy type metal adhesive. It will bond various materials such as ceramics and glass to metal, as well as metal to metal. Only pressure needed is to hold parts together during a 1-hr bake at 325 F. After curing, bond will withstand temperature up to 500 F for long periods of time. Compression strength is 18,000 psi;

shear strength at room temperature, 3500 psi. Adhesive is chemically inert to acids, alkalies and salt water. Made by **Carl H. Biggs Co.,** 2255 Barry Ave., Los Angeles 64, Calif.

For more data circle MD-99, Page 253

Air-Cooled Engines

Line of heavy-duty, air-cooled engines includes model AU85, a 3-hp engine which is only 13⅛ in. high. All engines in the AU series incorporate shell molded intake manifold and ports with smooth interior, Carter center-bowl carburetor which permits engine operation at extreme tilt angles, large diameter intake valve and high cooling capacity. An optional automatic ignition cut-off stops



the engine if lubricating oil level falls below the safe point. Models are also available for operation on kerosene. Also optional is the Contex ignition system in which breaker points and condenser are mounted outside the crankcase under an easily removable cap. Made by **Continental Motors Corp.,** 12800 Kercheval Ave., Detroit 14, Mich.

For more data circle MD-100, Page 253

Pressure Switch

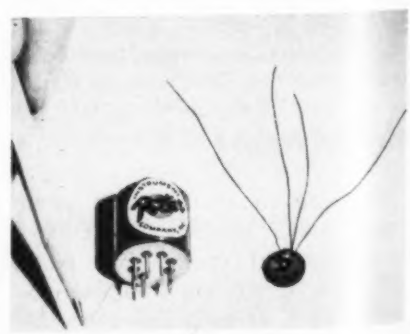
Easily installed, maintained and replaced series SG1-02 pressure switch is a gasket-mounted unit for application to hydraulic presses, production and processing machinery, machine tools and similar oil-hydraulic equipment. Three models are available for 100 to 1000, 100 to 2000 and 500 to 5000 psi ranges.

Pressure settings are adjustable throughout the complete range. All models measure 7$\frac{11}{16}$ x 3⅞ x 2 in. Nominal current ratings are 10 amp at 110-125 v ac for the lowest range model, 5 amp at 220-250 v ac for intermediate size and 3 amp at 440-460 v ac for the highest range. Subplate is available to permit mounting where a machined pad is not provided. Made by **Vickers Inc.,** 1400 Oakman Blvd., Detroit 32, Mich.

For more data circle MD-101, Page 253

Magnetic Core Transistors

Advantages of transistors and magnetic cores are combined in Magnistors, basic circuit elements applicable to high-speed computers, business data handling systems, automation control systems, high-speed counters and magnetic tape systems. They are available as components as well as in complete packaged systems. Two types are made: transient type acts as an amplifier in which extremely small



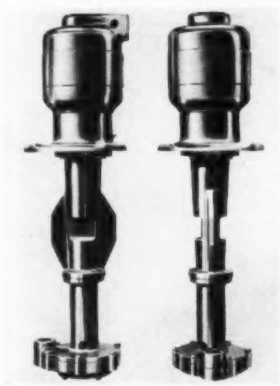
electrical signals can control other circuits having several thousand times the power; permanent two-state or bistable storage type device can be turned on and off by small electrical impulses. Latter

unit will "remember" information indefinitely, even when power is disconnected. Magnistors will last indefinitely and are not affected by temperature extremes. Operation is over frequency range from direct current to 30 million cycles per second. Made by **Potter Instrument Co.**, 115 Cutter Mill Rd., Great Neck, N. Y.

For more data circle MD-102, Page 253

Coolant Pump

One-piece electronically balanced shaft assembly which rotates on two heavy-duty ball bearings is incorporated in the model TL-15025K Gusher coolant pump. It is designed for center coolant trough

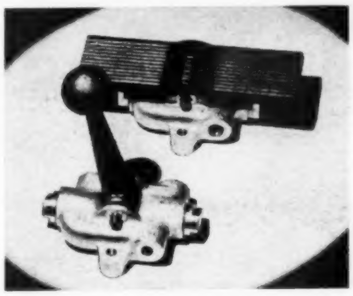


mounting on traveling base machine tool installations. The tapered tubular housing is provided with a reinforced narrow section for passage through the limited width slot in the trough cover. Packing glands and seals are above the liquid high level line, permitting handling of liquids contaminated by dirt, grit and abrasives. Built-in motor is $\frac{1}{2}$, $\frac{3}{4}$ or 1 hp. Made by **Ruthman Machinery Co.**, 1811 Reading Rd., Cincinnati 2, O.

For more data circle MD-103, Page 253

Three-Way Valve

Venturi-type model HF-3 hand and foot-operated three-way valve has built-in, full-flow capacity of $\frac{1}{4}$-in. ID pipe or equivalent of 50 cfm at 50 psi. Valve was designed for air, oil and water pressures to 200 psi and is recommended for small single-acting cylinders. It can be furnished either locking (two positions standard) or nonlocking and can be ordered locking with neutral. Spring return is also available and can be supplied on all nonlocking models for on or

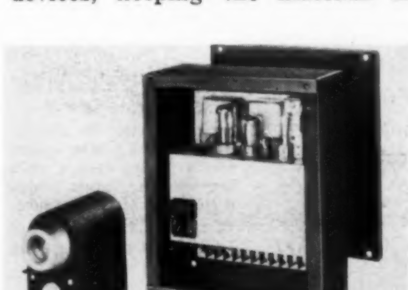


off positions. Valve body is aluminum alloy 195 and poppets are hard brass. Maximum operating temperature is 175 F. Made by **Airmatic Valve Inc.**, 7317 Associate Ave., Cleveland 9, O.

For more data circle MD-104, Page 253

Registration Control

Precise accuracy in automatic machine operations on paper, textiles, plastics, tin, steel or other sheet materials can be maintained by the type 23LF3 model 1006 registration control. Operating continuously over high and low speed ranges, it responds instantly to the appearance of a mark printed on material moving past it at speeds from 15 to over 500 fpm. Abrupt change in light intensity caused by passage of the mark actuates the control relay which will trigger speed correction devices, keeping the material in



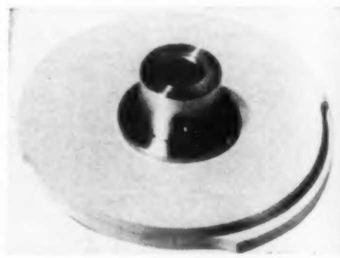
synchronization with machine operation. Response is to impulses as short as 0.0005-second. Several scanner models are available to accommodate reflectance characteristics of most materials. Mini-

mum speed of controlled material is 3 in. per second; maximum speed depends upon size of registration mark. Contacts are single-pole double-throw, rated at 10 amp, 115 v ac noninductive; 5 amp, 230 v ac noninductive. Made by **Electronics Corp. of America**, Photoswitch Div., 77 Broadway, Cambridge 42, Mass.

For more data circle MD-105, Page 253

Adjustable Cam Assembly

This precision cam assembly is used in applications requiring a physical displacement of any miniature switch or similar actuating device. The two stainless steel cams



can be rotated with respect to each other and locked at any timing position. Stainless steel shaft adapters are designed for 1/8, 3/16 and 1/4-in. shafts which have stainless steel setscrews for holding and sub-drill holes for fixed pinning. Made by **PIC Design Corp.**, 160 Atlantic Ave., Lynbrook, L. I., N. Y.

For more data circle MD-106, Page 253

Miniature Relays

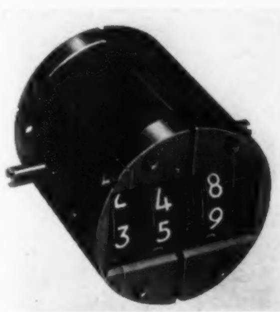
Three hermetically sealed miniature relays operate reliably under severe conditions of shock and vibration and at temperatures ranging from −55 to 125 C. Type DC-34 is a four-pole, double-throw relay with silver contacts, rated at 2 amp resistive load at 28 v dc or 115 v ac. Coil resistances are available to 30,000 ohms. Type DC-33C

operates with positive, snap-action contact switching. Double-pole, double-throw silver contacts are rated for resistive loads of 2 amp at 28 v dc or 5 amp at 125 v ac. Coils are available with resistance up to 15,000 ohms. Positive, snap-action contact switching is also characteristic of type DC-33C-AC. Contact arrangement and rating is identical to type DC-33C; coil is rated at 117 v ac. Specially compounded alloy contacts are available for all relays. Made by **Deltronic Corp.**, 1507 Riverside Dr., Los Angeles 31, Calif.

For more data circle MD-107, Page 253

Angle Indicator

Useful in clockwise, counterclockwise or reversible application, model 1502 angle counter indicates angular changes from 0 to 359 degrees, then back to 0 in 1-degree



divisions. One revolution of input shaft is equal to one revolution of the drum unit. Input speed is rated at 500 rpm. All internal parts are treated for corrosion resistance. Made by **Bowmar Instrument Corp.**, 2415 Pennsylvania St., Ft. Wayne, Ind.

For more data circle MD-108, Page 253

Explosionproof Motor

Made for class I, group D services for high inflammable gases and volatile liquids and class II, group F and G for combustible dusts, this fully enclosed motor is offered in ratings from 1 to 5 hp. It meets NEMA and National Board of Fire Underwriters specifications and is offered as type E with a sparkproof aluminum fan

(*Continued on Page* 298)

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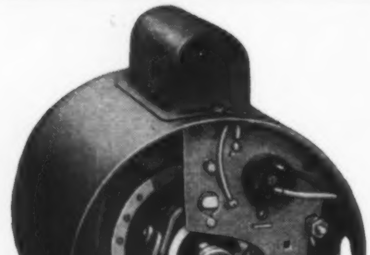
TYPE RK CAPACITOR-START



View with endplate removed showing terminal board on which thermal protector and quick-break switch are mounted. Note thickness of steel frame which has been machined for accurate endplate fit. Rigid base is welded directly to the frame.

Inside view of sleeve bearing endplate with seal removed to show felt packing used for lubrication. In addition to the continuous strip, a spring-loaded piece of felt makes constant-pressure contact with the shaft through an opening in the top of the bearing.

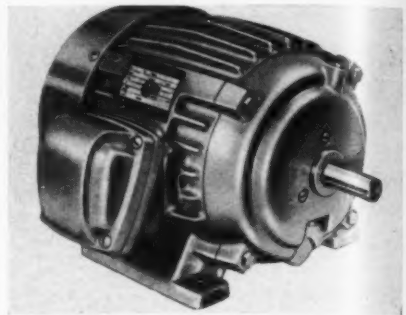
TYPE RB SPLIT-PHASE

View from front end of Type RB motor shows how motor is secured in the base by means of latches. The terminal board cover can be opened as shown or removed entirely by merely loosening the two screws which hold it in place.

Inside view of a sleeve bearing endplate with seal in place. Endplates are provided with ample ventilating openings, all located below the centerline fo dripproof construction.

New Parts

(*Continued from Page 295*)

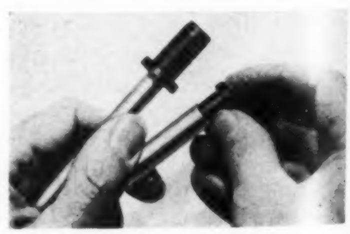


and type EN without a fan. Split dome conduit box is sealed, and internal bearing caps extending along the shaft prevent sparks from traveling to the exterior. Frame is one-piece cast iron with external ribs for reinforcement and heat dissipation. Drain plug can be furnished. Both types have asbestos-protected windings, Lubriflush lubrication and normalized castings. Made by **U. S. Electrical Motors Inc.,** P. O. Box 2058, Los Angeles 54, Calif.

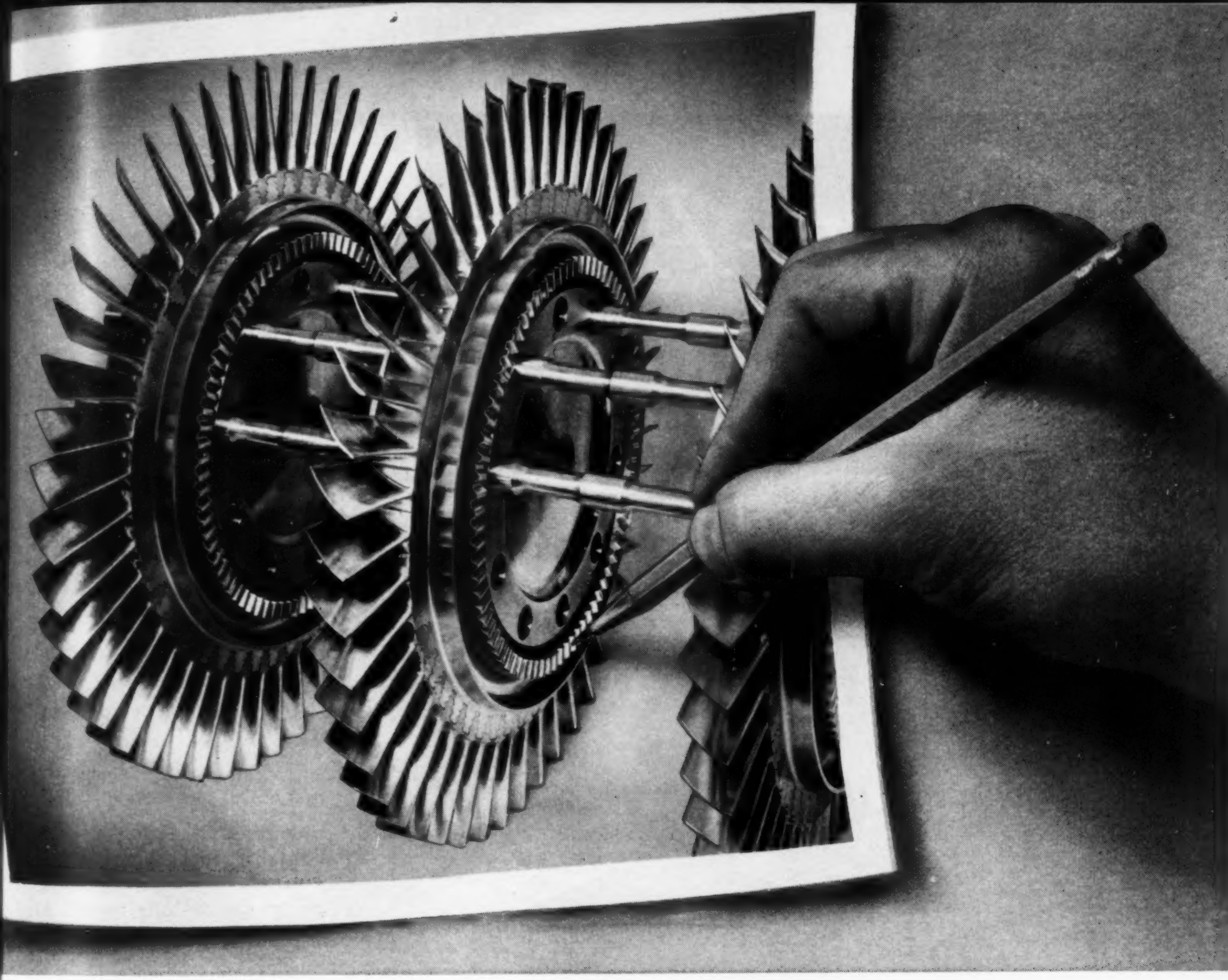
For more data circle MD-109, Page 253

Caps and Plugs

Shurclose protective closures protect threaded openings and connections against possible damage, prevent moisture or dust penetration, seal in gases and liquids, and



mask pipe or tube ends from paint spray and preservative finishes. Rubber caps and plugs are high-grade, sulphur-free black rubber or Neoprene, Hycar or natural rubber. Four types and 50 sizes are available to fit 1/16 to 2½-in. OD tubing as caps and 7/16 to 3-in. ID tubing as plugs. Plastic closures are molded vinyl or polyethylene. They are flexible, tough, and impervious to most commercial gases and fluids. They do not chip, shred or break under severe usage and are available in 19 sizes as caps for tubing ranging from



Can CURVIC® Couplings lower the cost of your product?

They have done so for scores of manufacturers, by reducing machining time, by saving time in assembly and by permitting more compact design.

Curvic Couplings are extremely accurate toothed connections which combine the functions of driving, centering and alignment.

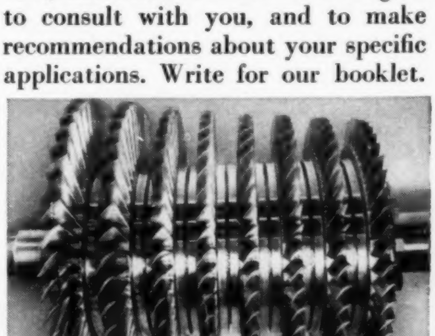
With Curvic Couplings, complex machine parts can be made in several smaller units and then bolted or otherwise fastened together. Experience has proved that fabrication of many large parts in smaller units has reduced the time spent in machining, simplified final assembly, and reduced over-all manufacturing costs.

And there is no sacrifice of precision—in fact, Curvic Couplings are so accurate that tolerances in the finished assembly can be held closer than when the part is made by any other means.

Curvic Couplings are used in such applications as heavy-duty gas turbine rotors like the one shown above, jet engines, crankshafts and camshafts.

In addition to fixed or permanent connections, Curvic Couplings can be produced in semiuniversal, and in releasing clutch types.

All types of Curvic Couplings are produced rapidly, economically, and with high precision, on Gleason Cutting and Grinding Machines. If you would like to know more about Curvic Coupling design or manufacture, the Gleason Works will be glad to consult with you, and to make recommendations about your specific applications. Write for our booklet.



Here is how CURVIC Couplings are used in the production of an 8-stage heavy-duty gas turbine rotor, holding it in perfect alignment under the severe stresses encountered at high speed.

GLEASON WORKS

Builders of bevel gear machinery for over 90 years

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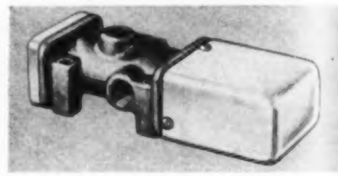
1/8 to 1½ in. OD or as plugs for tubing from 3/16 to 1⅝ in. ID. Made by **Ray A. Scharer and Co.**, 3000 E. Grand Blvd., Detroit 2, Mich.

For more data circle MD-110, Page 253

Three-Way Air Valve

Heavy duty Bel-Air valve, now available in a three-way series, is offered in ¼, ⅜ and ½-in. models for manual or electrical control. Solenoid-controlled, pilot-operated models offer a choice of 115, 230 or 440 v operation, with



the same solenoid used on all sizes. Mechanically-actuated models include hand lever, clevis, roller, foot pedal and treadle types. All actuators are interchangeable between valves of similar size. Removable torsion spring in lever bracket returns the valve when pressure is released. Valve bodies are cast bronze with a series of inserted chrome plated liners. Made by **Bellows Co.**, 230 W. Market St., Akron 9, O.

For more data circle MD-111, Page 253

Miniature Relay

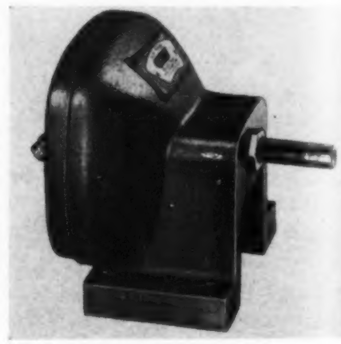
Heavy-duty contacts are now available on series 595 direct current telephone type relay. Unit can withstand inrush current of 50 amp at 28 v dc and is rated for continuous operation at 15 amp, 28 v dc. Standard 3-amp auxiliary contacts also can be sup-

plied. Unit is $1\frac{1}{4}$ in. long and weighs $2\frac{1}{2}$ oz. It is available as an open type relay or hermetically sealed to specification. Made by **Guardian Electric Mfg. Co.,** 1621 W. Walnut St., Chicago 12, Ill.

For more data circle MD-112, Page 253

Air Ram

Model 70 diaphragm-operated Speedy air ram has a power factor of 15 times air line pressure. The heavy-duty diaphragm, rigidly gripped between two ground surfaces, is leakproof. Unit does not require lubrication, and it can

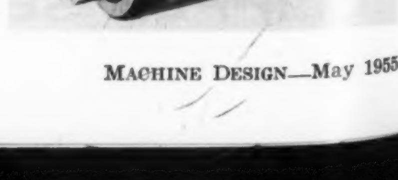


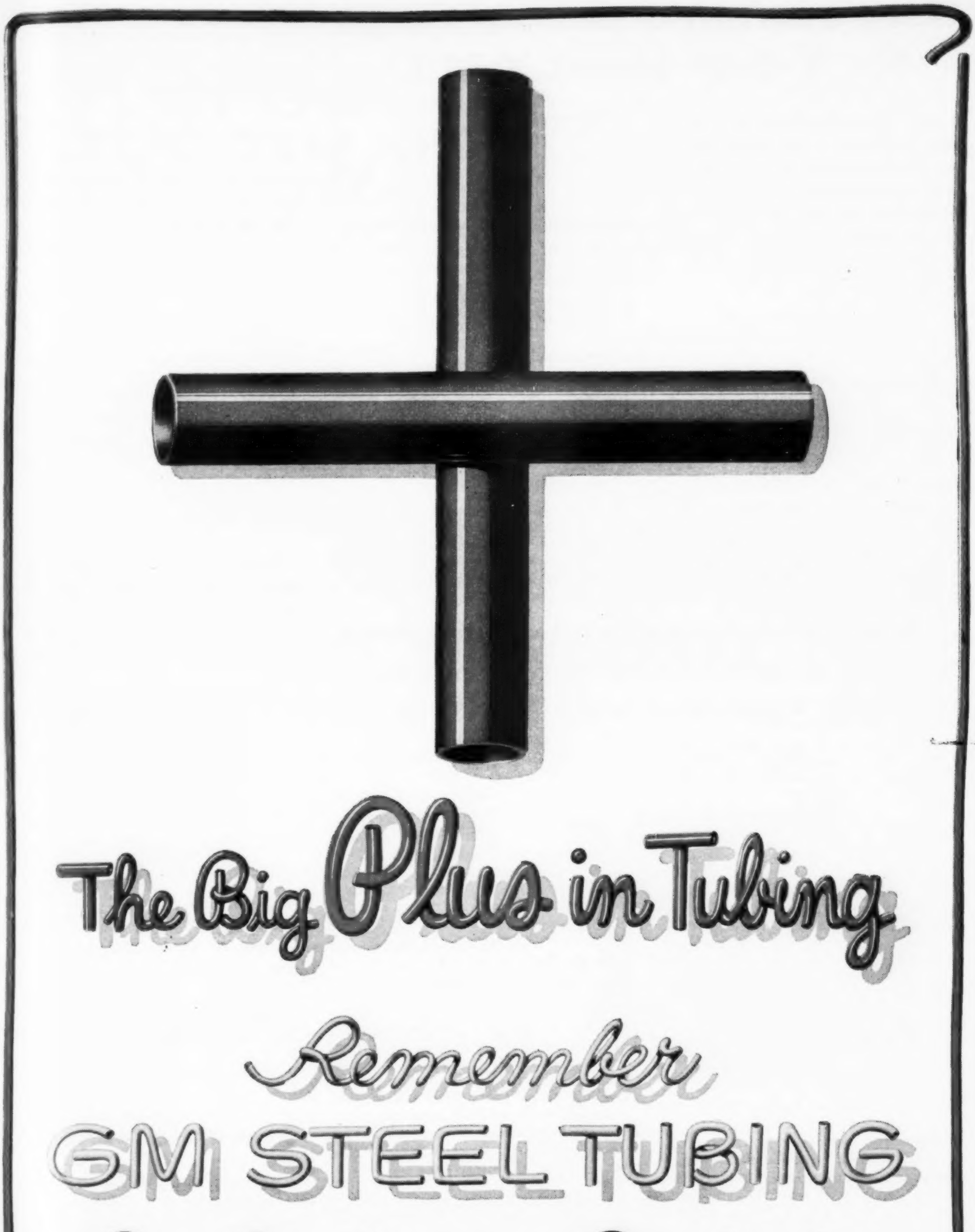
operate submerged in oils or solvents. Stroke is $\frac{5}{8}$-in. with spring return. Threaded ram screw has $2\frac{1}{2}$-in. adjustment. Any pressure up to 1 ton can be obtained when ram is used with pressure regulator. Available from **W. R. Brown Corp.,** 2701 N. Normandy Ave., Chicago 35, Ill.

For more data circle MD-113, Page 253

Potted Resistor Network

Potted resistor network is for resistance circuitry applications requiring miniaturization, rapid assembly, ease of replacement, efficiency and design flexibility. Made to individual requirements, net-





GM STEEL TUBING BY ROCHESTER PRODUCTS, DIVISION OF GENERAL MOTORS, ROCHESTER, N.Y.

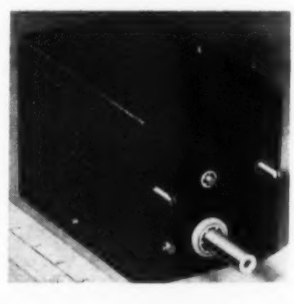
New Parts

works can contain any given number of precision wire-wound resistors of specified values in a compact unit of any specified shape or size. They are hermetically sealed, lightweight, fungus resistant, well insulated and corrosion resistant. Ambient operating temperatures are up to 150 C. Mounting can be wire lead, plug-in, screw type or any other style. Chassis mounting provides for higher wattage ratings. Plug-in unit illustrated contains five wire-wound resistors. Made by **I-T-E Circuit Breaker Co.**, Resistor Div., Nineteenth and Hamilton Sts., Philadelphia 30, Pa.

For more data circle MD-114, Page 253

Limit Switch

Limits of this gear-driven limit switch can be adjusted by means of two slotted screws while the equipment on which it is installed is in operation. Gears need not be

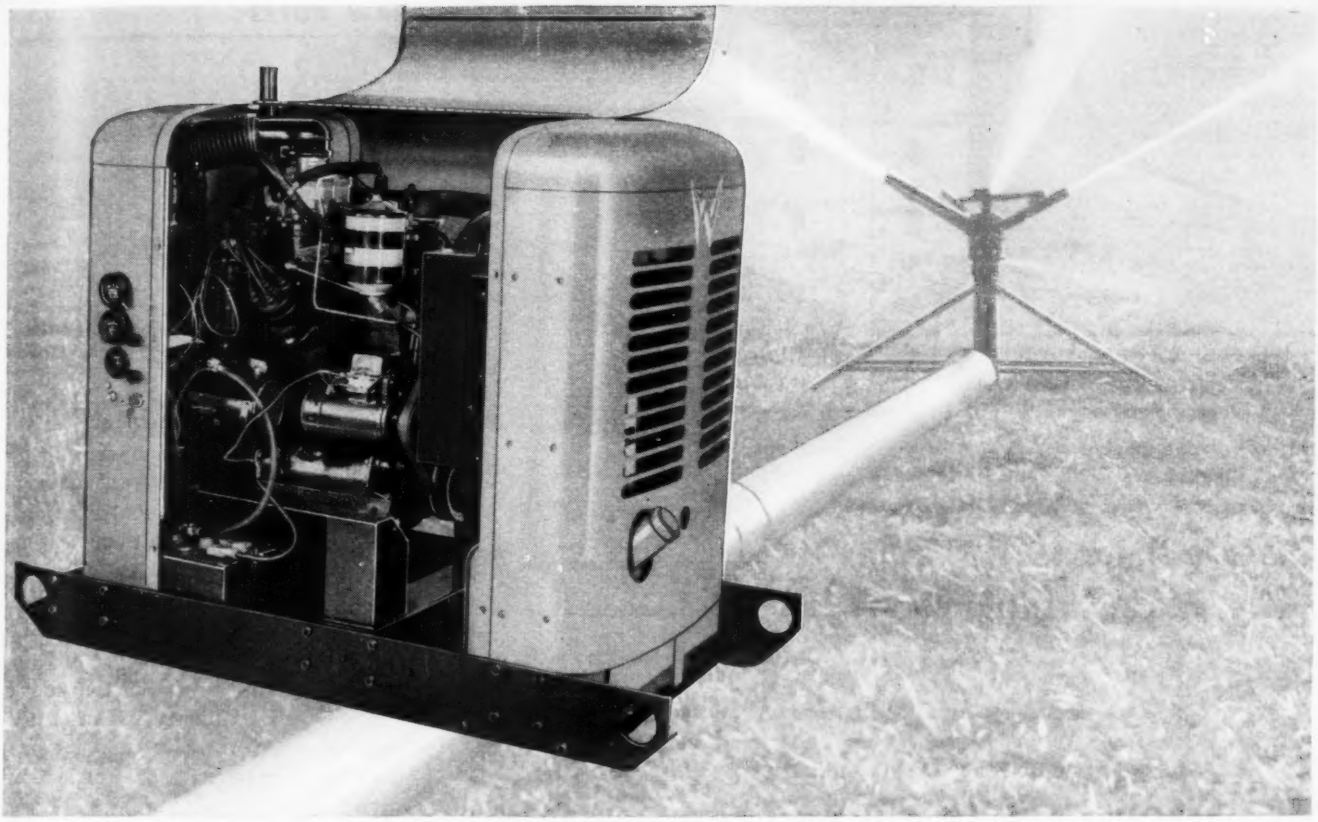


disengaged. Switch is available for use up to 550 v and is easily installed and wired. Hardened steel drive shaft operates on precision bushings. Made by **Clark Door Co. Inc.**, 515 Hunterdon St., Newark 8, N. J.

For more data circle MD-115, Page 253

Double Hydraulic Pumps

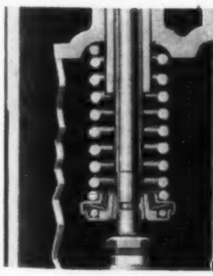
PF-100 series 2000-psi variable delivery hydraulic power units are available as double pumps equipped with integral valve panels. Comprising two standard dual vane interchangeable pumping cartridges, with common driveshaft and common inlet but separate discharge outlets, the integral units can be used to supply power to two separate systems or to a single two-



'Jeep'® ENGINE RUGGEDNESS...

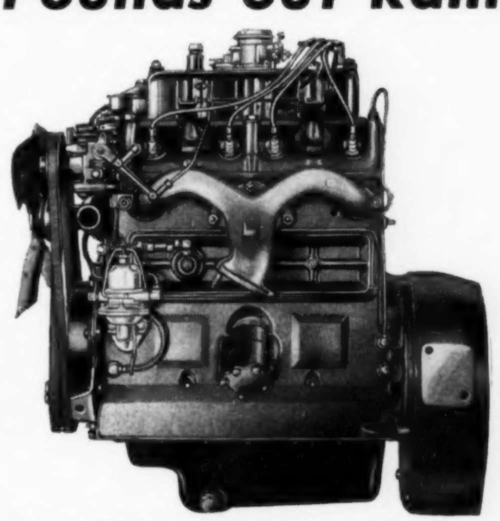
Steady Thunder that Pounds out Rain

Steady does it in irrigation. That's why **proven-in-action** 'Jeep' engine features designed into 4 or 6 cylinder POWER GIANT Industrial Engines have scored high with farmers when these durable engines have powered their irrigation pumps. Wherever constant, dependable service is a **must**, POWER GIANT Engines are in demand. Complete Willys Power Units are available, or engines can be installed directly into your equipment. Write today for technical bulletins.



POSITIVE Valve Rotators

Hard-faced, nickel chrome alloy steel valves in POWER GIANT Engines are equipped with Positive Rotators to increase valve life, and minimize carbon hazard to engine life. Valve turns with each opening, ejecting carbon and keeping valve seats and stems clean and workable. Just one more 'Jeep' engine feature for rugged staying power.



Model	JEEP (L-4)	HURRICANE (F-4)	LIGHTNING (L-6)
Range Max. bhp	22-60	22-70	28-75
Range of Speed	1200-4000	1200-4000	1200-4000

'Jeep'® POWER GIANT

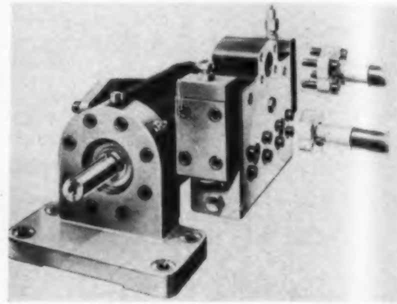
Industrial Engines and Power Units

WILLYS MOTORS, INC. • *Industrial Engine Department*

BUILT WITH Jeep® RUGGEDNESS

1460 NORTH COVE BLVD. TOLEDO, OHIO

New Parts



pressure circuit. They are especially adapted to the operation of circuits requiring substantial variation in pump volume. Pumping cartridges have capacities of 3, 5, 8 and 11 gpm, rated at 1200 rpm. Total pump capacities range from 6 to 22 gpm. Interchangeability of cartridges, or cam rings only, if desired, permits up to ten quick changes of capacity. Either or both pumps or valve panel alone may be removed for inspection without dismantling piping. Made by Dudco Div., **New York Air Brake Co.,** 1700 E. Nine Mile Rd., Hazel Park, Mich.

For more data circle MD-116, Page 253

Plastic Coatings

Properties obtainable with high-temperature baking are inherent in Perma-Skin air-drying epoxy coatings. Thus items too large or otherwise impractical to bake can be coated. Coatings have good adhesion, abrasion resistance, durability, flexibility, acid and alkali resistance and solvent resistance. Made by **Dennis Chemical Co.,** 2701 Papin St., St. Louis 3, Mo.

For more data circle MD-117, Page 253

Pushbutton Timer

Improved 110 series push-button-operated electrical timer has heavy-duty switch, solderless snap-on terminals for easy installation and enclosed switch and gear mechanisms. Accurate, fixed timing periods range from 20 seconds to 24 hours. Telechron synchronous motor operates on 110 or 220-v ac, 25, 50 or 60 cycles. Unit is rated 30 amp and is equipped with tabs for AMP Faston terminals. For applications requiring a

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by reduced inventory

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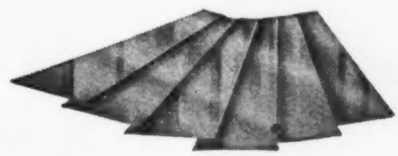
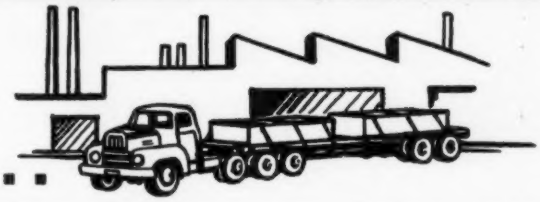


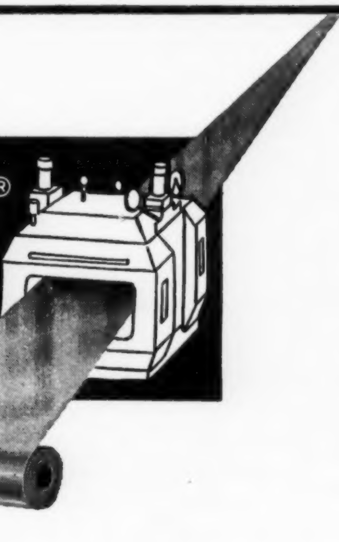
by faster service

Your steel distributor, being nearer to you, assures you of quicker deliveries to meet production schedules. ■ ■ ■



by specifying

MicroRold®
STAINLESS STEEL



with "Thinness Control"

MicroRold Stainless Steel Sheet is available through steel warehouse distributors strategically located at points most accessible to fabricators of stainless steel products. These distributors, being closely associated with the industry, not only facilitate the selection and delivery of stainless sheets but can also provide technical assistance on your stainless steel fabricating problems.

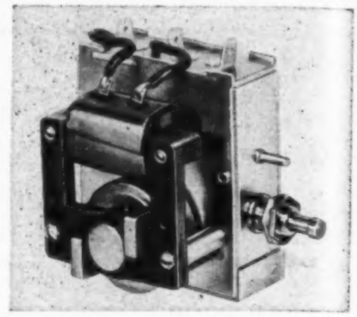
Your steel distributor will explain the advantages of buying MicroRold with "Thinness Control." This "Thinness Control" in the manufacture of MicroRold stainless sheets means the decimal thickness is uniform throughout the length and width. MicroRold is rolled to exceptionally close tolerances, as low as 3% average (plus or minus) as compared to the A.I.S.I. allowable of plus or minus 10%. Each .001″ in thickness saved results in a savings of 1.26 pounds when figured on a standard 36″x 120″ sheet. MicroRold's controlled accuracy of gauge gives you more stainless area per ton or the equivalent area with lesser weight.

Consult your nearest MicroRold Stainless Steel Distributor. He will gladly tell you the MicroRold story.

WASHINGTON STEEL *Corporation*

Washington, Pennsylvania

New Parts

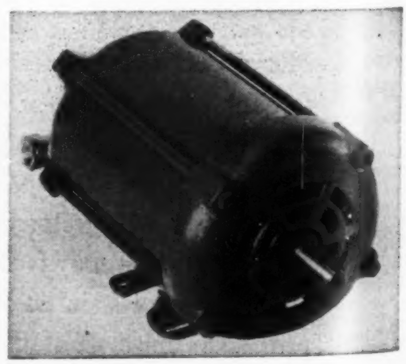


fixed "on" period, it is used in electric hand dryers, room ventilators, air conditioners, dehumidifiers, paint mixing machines, duplicating equipment and in heat treating and lighting. Made by **Miller-Harris Instrument Co.**, Dept. A, 601 E. Ogden Ave., Milwaukee 2, Wis.

For more data circle MD-118, Page 253

Explosionproof Motors

Designed for long life and safe operation in hazardous atmospheres, line of explosionproof fractional horsepower electric motors is UL-approved for class I, group D; and class II, group E, F and G atmospheres. Oxidation resistant grease in ball bearings also



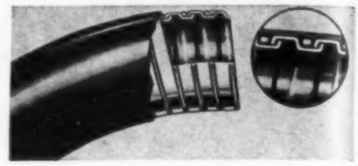
resists moisture attack for minimum maintenance. Design employs overbolt construction and heavy, cast iron end shields. Made by General Purpose Component Motor Dept., **General Electric Co.**, Schenectady 5, N. Y.

For more data circle MD-119, Page 253

Flexible Metal Conduit

Black waterproof synthetic cover encloses type U20SCB flexible metal electrical wiring conduit

New Parts

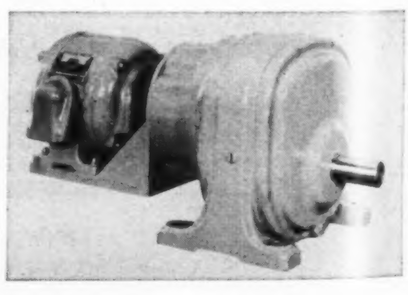


which has square locked construction, galvanized steel core and is aluminum wire-wound on sizes ⅜ to ¾-in. Type U20SCG has gray synthetic cover and is offered in ⅜ to 2 in. conduit sizes. Conduit provides complete protection against moisture, dirt, oil, fumes and chemicals. It is suited for flexible connections in tight places, for connecting wires on machinery operating in excessive oil or moisture and for applications where extreme vibration is present. Made by **Universal Metal Hose Co.,** 2133 S. Kedzie Ave., Chicago 23, Ill.

For more data circle MD-120, Page 253

Speed Reducer

Slo-Speed gear motor is available for separate motor mounting. It can be mounted on floor, wall or ceiling, with the shaft horizontal or vertical, without modification. Unit can be supplied with



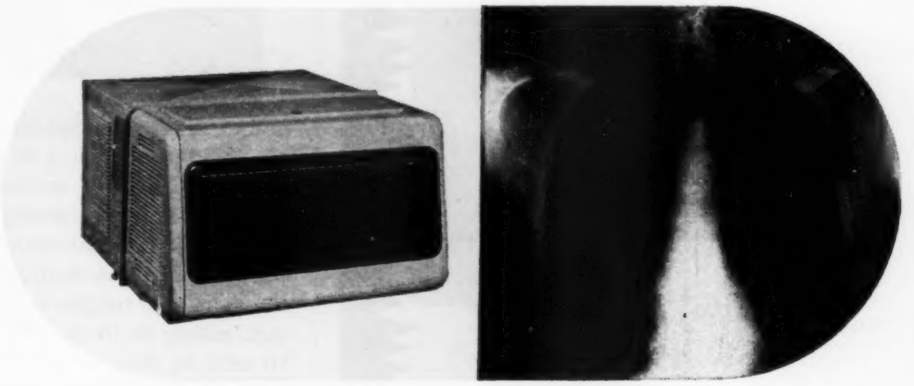
any foot-mounted dripproof, totally-enclosed fan-cooled, explosionproof, wound-rotor, dc motor. Compact reducer has positive oil seals, drip-splash lubrication and low output shaft. Made by **Sterling Electric Motors Inc.,** 5401 Telegraph Rd., Los Angeles 22, Calif.

For more data circle MD-121, Page 253

Miniature Toggle Switch

Corrosion resistant and explosionproof Hermetronic K-W toggle switch is capable of 300,000 cycles and is able to withstand accelera-

Howard Fractional H. P. Motors



are used in quantity applications

from air conditioners to X-ray machines

#3000 GEAR MOTOR—OUTPUT 120 IN.-LB.

#11A—1/45 to 1/30 H.P.

#512—1/20 to 1/10 H.P.

#5000—1/15 to 1/8 H.P.

#2400—SERVO MOTOR

#700—1/8 to 1/2 H.P.

#2800—1/30 to 1/70 H.P.

#2500—1/300 to 1/1400 H.P.

who will make it "A" to "Z"?

Whether your application begins with the letter Z or any letter from A to, Howard will be happy to quote on your motor requirements. 85,000 applications prove the versatility of Howard motors—the largest line of fractional motors in the entire industry. Chances are Howard can fill your requirements with the right motor at the right price.

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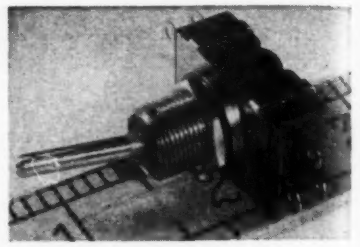
DIVISIONS: EMC ELECTRIC MOTOR CORPORATION • CYCLOHM MOTOR CORPORATION • REP RACINE ELECTRIC PRODUCTS

New Parts

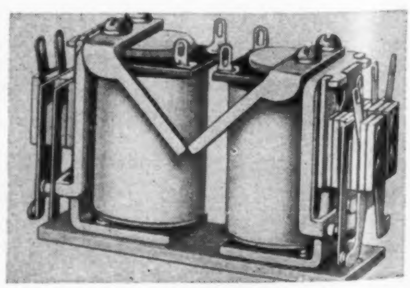


tion, impact and vibration to 200 *g*. Switch case is 1.15 x 0.625 x 0.415-in. Silicone rubber bonded to stainless steel bushing of switch provides panel sealing and permits control of hermetically sealed assemblies by toggle action. Contact rating is 10 amp at 125 v ac, 10 amp at 30 v dc and 1.5 amp at 125 v dc. Insulation resistance is better than 1000 megohms at 70 F. Dielectric strength is checked at 1000 v rms. Made by **General Hermetic Sealing Corp.,** Hermetronic Controls Div., 99 E. Hawthorne Ave., Valley Stream, N. Y.

For more data circle MD-122, Page 253

Latch-In Relay

The armature mechanically latches in the energized position in this miniature latch-in relay. Device comprises an operating relay and a reset relay with mechanically interlocking arms. When the operating coil pulls the armature into the energized position, the levers mechanically lock the



armature in place. Armature may be reset electrically or manually. Latching levers are heat treated, hard chrome plated alloy steel. Available for 6, 12, 24, 48 and 115 v dc operation, relay can be furnished with various contact ratings and contact combinations. Size of relay is 2⅝ x 1 x 1⅝ in. Made by **Magnecraft Electric Co.,** 3350T W. Grand Ave., Chicago 51, Ill.

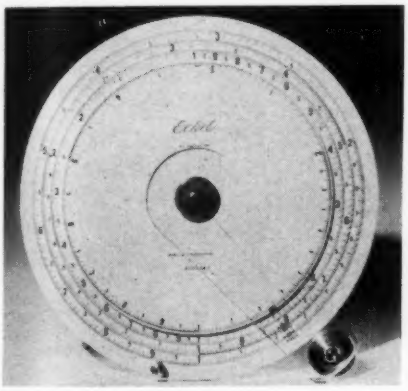
For more data circle MD-123, Page 253

ENGINEERING DEPARTMENT

EQUIPMENT

Circular Slide Rule

Computations are made on this circular slide rule by dialing in the numbers with the cursor, which can be locked in place. Scale division numbers face the operator as on a clock dial. The problem



solution, which never runs off the scale, is always read at the same stop position on the answer dial. Scales are identified on the cursor, and average scale length is 17 in. Precision spaced division lines are on white-faced metal. Instrument has deci-trigonometric scales on the back. Made by **Lithocalculator Co.**, 31 St. Joseph St., Arcadia, Calif.

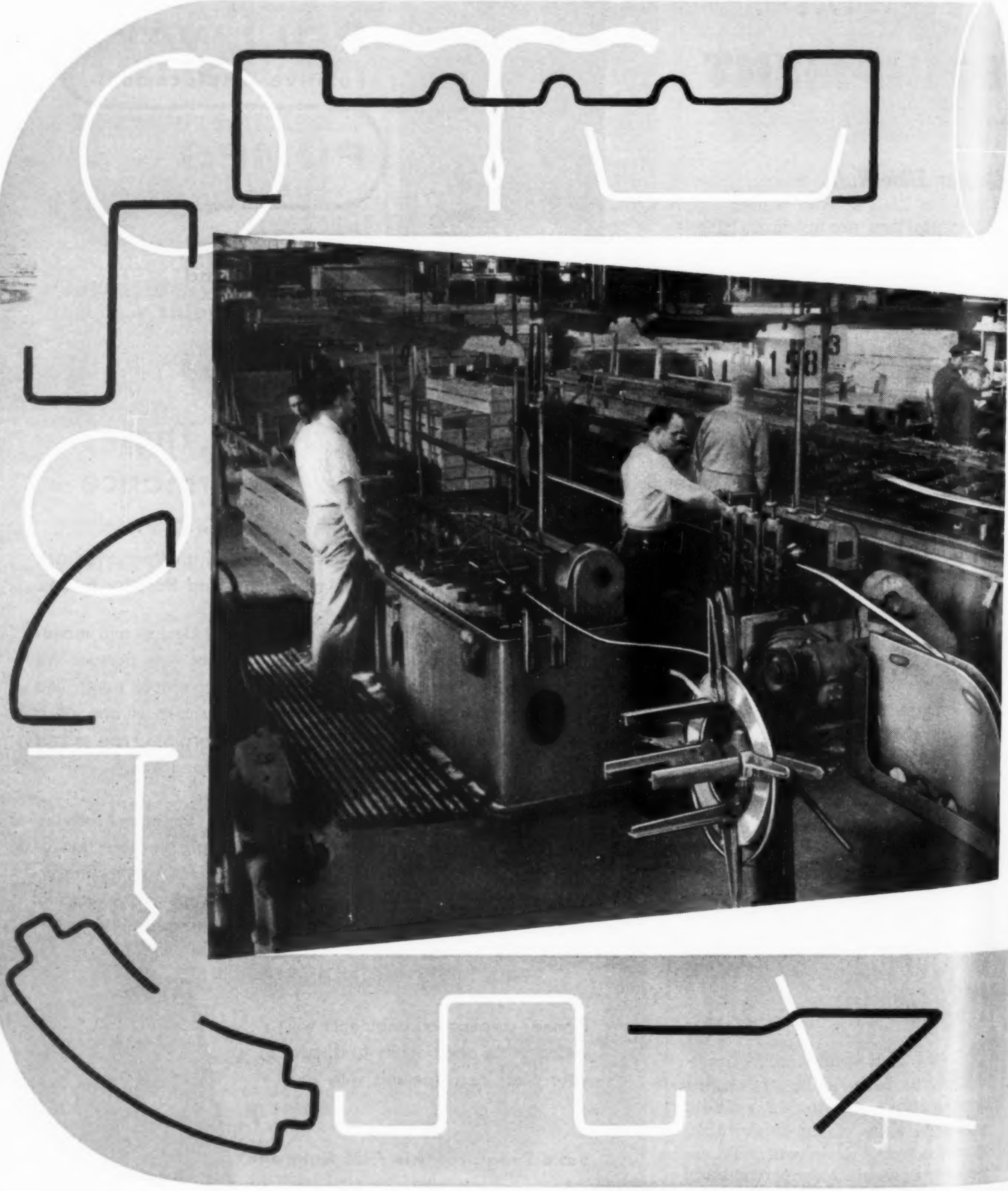
For more data circle MD-124, Page 253

Duplicator

Originals of engineering drawings up to 24 x 36 in. are copied by reduction onto the 12 x 18-in. sensitized plate of the model 1218 XeroX copying equipment. Transfer is then made to paper masters by Xerography, a dry electrical process requiring no intermediate negative, for runoff of multiple copies on an offset duplicator. Drawings of 12 x 18 in. can be copied size-to-size, while several small drawings at a time can be copied at the same size or enlarged

(*Continued on Page* 318)

For Economy, Design Freedom,



Dimensional Accuracy and Better Finishes . . . Specify

ALUMINUM Roll Formed Shapes from REYNOLDS

Rolling from coil stock permits savings that are impossible when working from flat sheet.

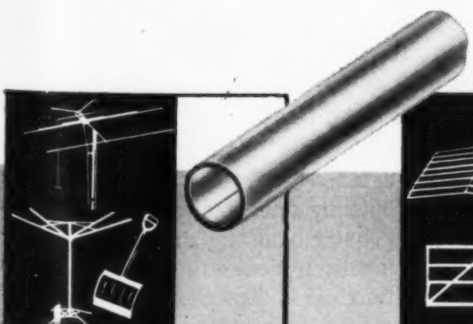
Therefore if you are fabricating a complex shape from flat sheet, or if you require a shape in long lengths, it will pay to switch to aluminum roll formed shapes from Reynolds.

Reynolds roll forming can produce a wide range of easily fabricated shapes that aid in design flexibility. Closer tolerances on Reynolds roll formed shapes mean dimensional accuracy; better as-fabricated finishes often mean a more attractive product without additional finishing operations.

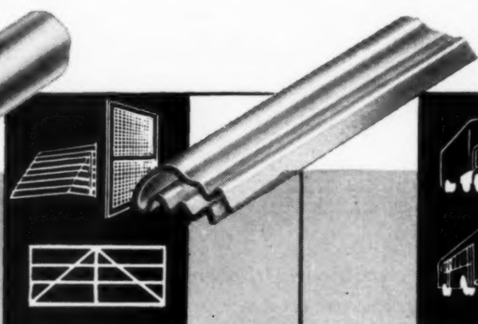
Reynolds sizable investment in roll forming machines and tooling, Reynolds technical advisory service and Reynolds quality control from mine to finished product assure prompt, economical production of quality roll formed shapes. For details, contact the Reynolds office listed under "Aluminum" in your classified telephone directory or write *Reynolds Aluminum Fabricating Service, 2061 South Ninth St., Louisville 1, Ky.*

Write for your free copy of the 8-page brochure, "Aluminum Roll Formed Shapes by Reynolds."

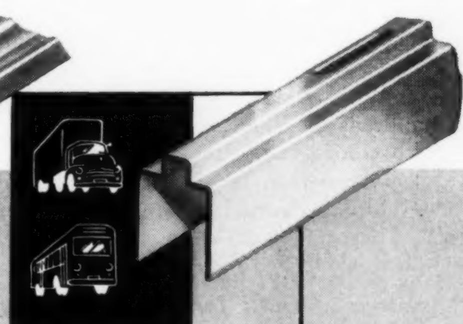
See "Mister Peepers", starring Wally Cox, Sundays on NBC-TV



High strength and superior finish of aluminum roll formed tubing pays off in TV antenna, snow shovel handles, clothes dryers and many other products.



Parts for window screens, farm gates, car ports, awnings and other building products are economically produced with aluminum roll formed shapes.



Many complex truck and trailer framing members, bus trim strips and other parts are easily fabricated with aluminum roll formed shapes.

FABRICATING SERVICE

ROLL SHAPING • TUBE BENDING • WELDING • BRAZING • FINISHING

Engineering Equipment

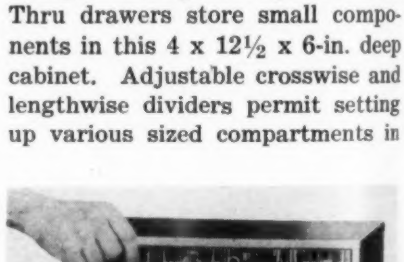
(*Continued from Page 315*)

individually to 12 x 18 in. Up to 100 copies can be made in about 5 minutes. Copying equipment uses precut paper and consists of copying camera, charge unit, developing and cleaning trays, transfer unit and fuser for making the image on the paper master permanent. Made by **Haloid Co.**, 555 Haloid St., Rochester 3, N. Y.

For more data circle MD-125, Page 253

Plastic-Drawer Cabinet

Eight transparent plastic See-Thru drawers store small components in this 4 x 12½ x 6-in. deep cabinet. Adjustable crosswise and lengthwise dividers permit setting up various sized compartments in



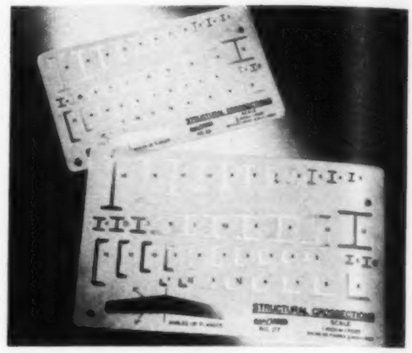
the 5⅞ long, 2¾ in. wide and 1 7/16-in. high drawers. Safety catches prevent drawers from opening accidentally. Slots are provided on the drawer fronts for labels, if desired. Steel cabinet is finished in silver-gray baked enamel and has protective rubber feet. Available from **General Industrial Co.**, 5738 N. Elston Ave., Chicago 30, Ill.

For more data circle MD-126, Page 253

Structural Templates

No. 27 template, with scale of 1 in. = 1 ft, and No. 28, with scale of ¾-in. = 1 ft, cover standard structural shapes and have ranges of I-beams from 3 to 18 in., broad-

Engineering Equipment

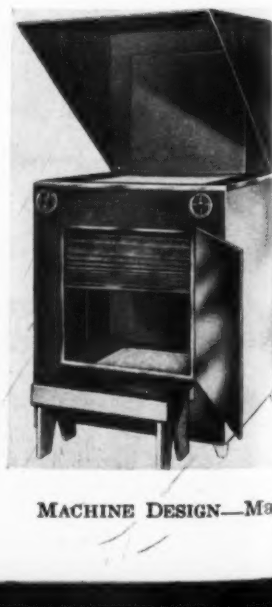


flanged I-beams from 3 to 12 in., channels from 3 to 15 in. and angles from 2 to 8 in. For I-beams and channels, medium weights have been selected for the proportional dimensions (height x width), while the broadflanged I-beams and angles have the standard dimensional proportion of width = height. Templates are 0.030-in. matte finish plastic. All cutouts are precision milled. Made by **Rapidesign Inc.,** P. O. Box 592, Glendale, Calif.

For more data circle MD-127, Page 253

Enlarging, Reducing Camera

Opaque or transparent drawings, as well as three-dimensional objects which can be placed on the 29 x 29-in. copyboard, can be projected four times larger or smaller than their original size by the Camera Lucikon. The image is projected through and upon a 24 x 24-in. working surface. Operator may view the image for comparison purposes, trace the projected image or make a photographic negative or photocopy. Operation of the camera is controlled by two



handwheels. Camera, which can be used in a normally lighted office, has an automatic cooling system. The unit is 36 in. wide, 30 in. deep and 76 in. high, including hood. Made by **M. P. Goodkin Co.,** 889 Broad St., Newark 2, N. J.

For more data circle MD-128, Page 253

Tracing Paper

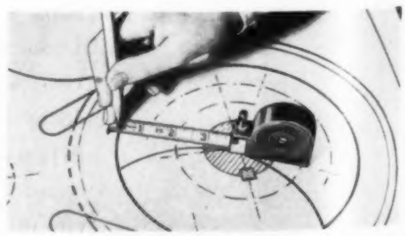
Transparentizing materials and paper are fused together at high temperatures to produce PTM paper, which looks and prints like a

film. The transparent paper has an evenly textured surface and is dimensionally stable. Made by **Frederick Post Co.,** 3650 N. Avondale Ave., Chicago 18, Ill.

For more data circle MD-129, Page 253

Beam Compass Rule

Circles up to 12 ft in diameter can be drawn with this Swedish-made beam compass rule. Device is held in place by depressing center point, which is a retractable thumbtack. Tape locks at desired



radius, and circle is drawn with a pen or pencil inserted in a hole at the end of the tape. Steel tape is marked with 1/32-in. graduations. Available from **Walpole Co.,** Dept. 140, 419 Boylston St., Boston 16, Mass.

For more data circle MD-130, Page 253

THE ENGINEER'S

Library

Recent Books

A Treatise on Applied Hydraulics. *By Herbert Addison; 732 pages, 5½ by 8½ inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, *$9.50 postpaid.*

Now in its fourth edition, this volume presents direct explanations of hydraulic principles and also serves as a guide to sources of more detailed information. Part 1 discusses fundamental principles in eight chapters on such subjects as liquids at rest and in motion; flow through orifices, over weirs, through closed conduits and along open channels; dynamic pressure of liquids; and radial and rotary motion of liquids. Part 2, on practical applications, encompasses 11 chapters on pipe and pipe systems; control of water in open channels; other flow problems; hydraulic machines; construction and performance of hydraulic turbines; pumping machinery; hydraulic transmission and storage of energy; and hydraulic measurement.

•

The Insulation of Electrical Equipment. *Edited by Willis Jackson, director of research and education, Metropolitan Vickers Electrical Co., England; 350 pages, 5½ by 8½ inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, *$7.75 postpaid.*

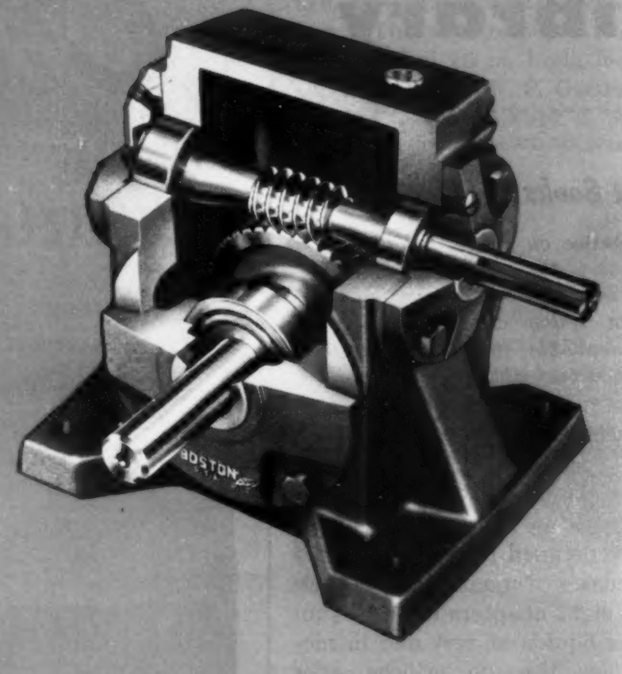
This book covers the subject of insulation with direct reference to the design, manufacture and testing of electrical equipment. It is a compilation of the lectures delivered at a post-graduate summer session held in the electrical engineering department of London's Imperial College. Subjects

(*Continued on Page* 328)

THE NEW 100 REDUCTORS

BOSTON Gear®

again sets the standard for cost-wise speed conversion



The New 100 SERIES is designed for peak efficiency and new economy by industry's largest, most experienced manufacturer of standard STOCK speed reduction units . . . BOSTON Gear.

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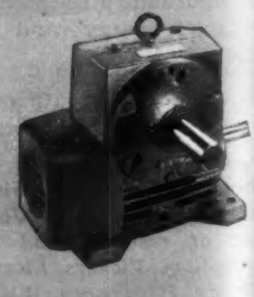

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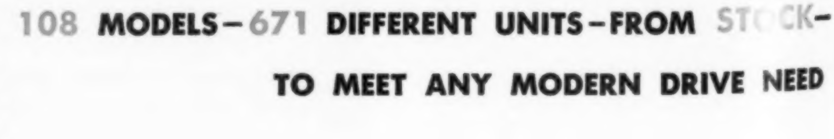

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The Engineer's Library

(*Continued from Page* 325)

covered include general properties of insulation, permittivity and dielectric loss, dielectric breakdown, classification and review of materials, communication components, power cables and capacitors, electrical machines, power transformers, switchgear and insulation testing. All types and sizes of equipment are included.

•

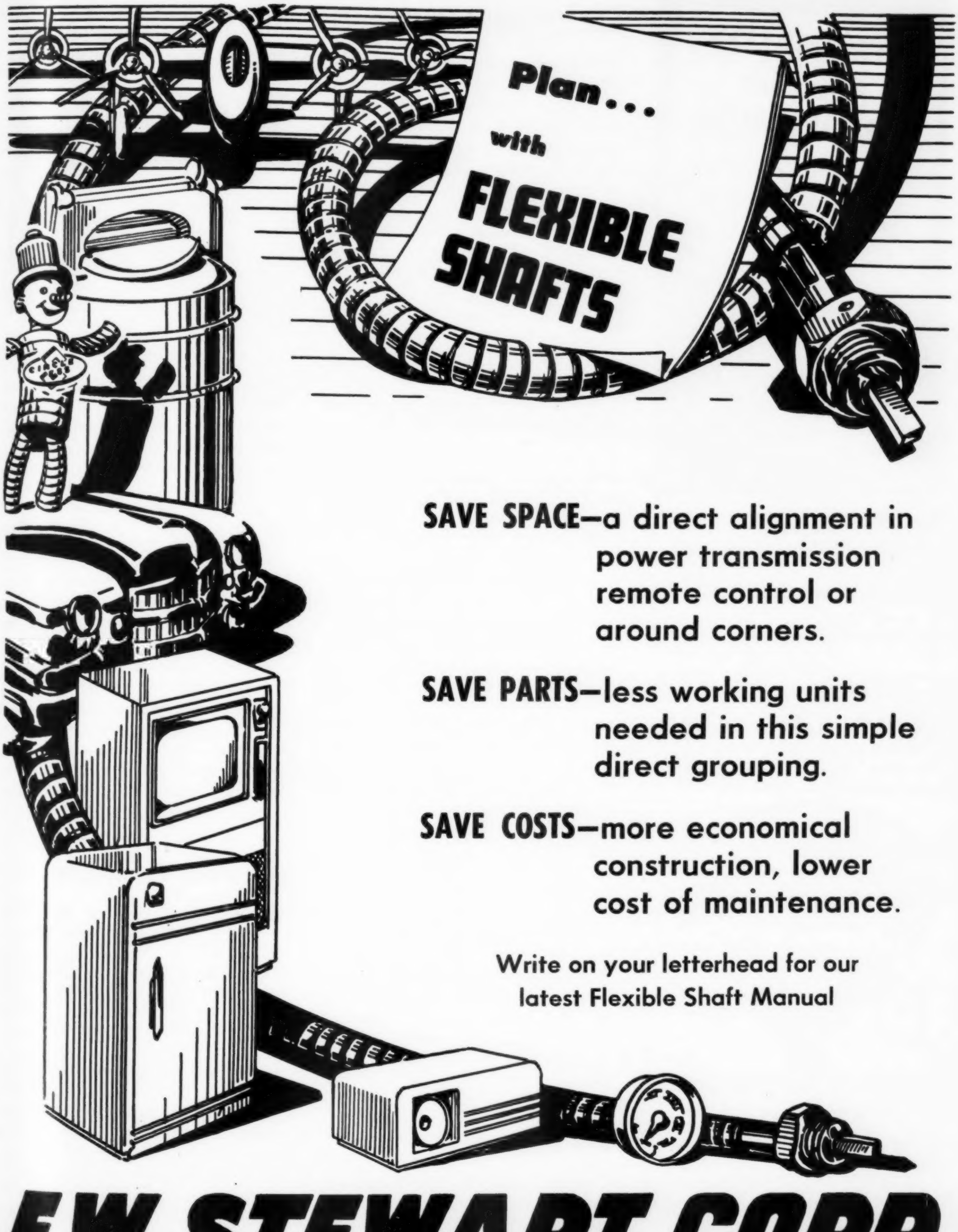
Materials for Product Development—1954. 159 *pages,* 6 *by* 9 *inches, clothbound; published by Clapp & Poliak Inc., New York; available from* MACHINE DESIGN, $7.50 *postpaid.*

This book contains the proceedings of the Basic Materials Conference held in Chicago in May, 1954. Organized in six sections, the first section, on materials of the future, covers new developments in engineering materials, rockets and guided missiles. This is followed by a section on new metal-forming processes, including precision casting, powder metallurgy, forging, extrusion and stamping. The third section, on nonmetallic materials, discusses plastics, carbon-graphite, ceramics and glass. The fourth section deals with adhesives and adhesive bonding of metals and plastics. A discussion of corrosion protection covers heat-resistant protective coatings for steel in the fifth section. Devoted to materials management, the sixth section offers a method for setting up and operating a materials department. Questions and answers appear at the end of each section.

•

The Physics of Experimental Method. *By H. J. J. Braddick, senior lecturer, University of Manchester, England;* 424 *pages,* 5¼ *by* 8½ *inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, $7.00 *postpaid.*

This book emphasizes the principles of physical experiment, currently available resources and limitations of contemporary technique. It is concerned with statistical



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analysis of errors, reduction of observation and essential dependence of physical measurement on the properties of various materials. Included in ten chapters are discussions on errors and the treatment of experimental results, mechanical design, construction materials, vacuum technique, electrical measurements, electronics, optics and photography, natural limits of measurement, and some techniques of nuclear physics.

♦

Analog Methods in Computation and Simulation. *By Walter W. Soroka, professor of engineering design, University of California; 404 pages, 6 by 9 inches, clothbound; published by McGraw-Hill Book Co. Inc., New York; available from* MACHINE DESIGN, $7.50 *postpaid.*

This text and reference book describes mechanical, electro-mechanical, electrical and electronic analog components for performing basic mathematical operations. It shows how such components may be combined into mathematical machines for solving simultaneous, polynomial and differential equations.

The first two chapters deal with computing elements. Chapters 3 and 4 cover simultaneous linear and nonlinear equations. Chapters 5 and 6 discuss mechanical and electronic differential analyzers. The final three chapters show how dynamic analogies, finite difference networks, membrane analogies and conducting sheets of uniform and variable thickness may be applied to the simulation of various physical systems and to the solution of differential equations.

New Standards

NEMA Standards Publication for Motors and Generators, MG1-1955. 243 *pages,* 8½ *by* 11 *inches, ringbound, paper covered; available from National Electrical Manufacturers Association,* 155 *East 44th St., New York* 17, *N. Y.,* $9.50 *per copy.*

Superseding Publication No. MG1-1949, the standards appearing in this book provide practical information concerning construction, testing, performance and manufacture of ac and dc motors and generators. They do not apply to heavy traction motors for railroads, motors for mining locomotives, arc-welding generators, toy motors and generators, nor to electric fans of the desk, bracket or ceiling types. These standards are generally used by the electrical industry to promote production economies and to assist users in the proper selection of motors and generators.

Manufacturers' Publications

Rod, Bar and Wire Product Information Book. 170 *pages,* 5 *by* 8¼ *inches, clothbound; available from Technical Editor, Kaiser Aluminum & Chemical Sales Inc.,* 22 *N. LaSalle St., Chicago* 1, *Ill., on company letterhead request, or* $2.00 *per copy.*

This publication is designed to assist engineers and designers in the selection and specific use of the most suitable aluminum rod, bar and wire for various applications. Contents deal with production of aluminum and its specific properties and characteristics, as well as new data regarding various alloys, their applications, fabrication and finishing methods.

Government Publications

Mechanical Failure of Metals in Service. *By John A. Bennett and G. Willard Quick;* 38 *pages,* 8 *by* 10¼ *inches, paperbound; available from Superintendent of Documents, U. S. Government Printing Office, Washington* 25, *D. C.,* 30 *cents per copy.*

This booklet, National Bureau of Standards Circular 550, describes 35 cases representing the most frequently observed types of failures of metal parts in service. Factors of design, fabrication, or use contributing to these failures are presented. The characteristics by which the various types of fractures can be recognized are discussed, and precautions to reduce mechanical failure of metals are included. The booklet is liberally illustrated with photographs of failures.

Surface Finish

(*Continued from Page* 155)

the abstracted articles. The abstracts are listed by years, generally in order published, and numbered. The numeral preceding the dash indicates the arrangement in this paper; the numeral following the dash designates the year of the publication. As an example of this system, abstract 7-52 is, in this paper, number 7 published in 1952.

ACKNOWLEDGMENTS: The writer sincerely appreciates the permission of the American Society for Metals, Cleveland, and the Industrial Arts Index, New York, for permission to use abstracts from their publications. The assistance of these two organizations has made possible the compilation of this review of surface finish material. These two sources are identified on the applicable abstracts as follows:

American Society for Metals, Review of Metal Literature . . . . ASM
Industrial Arts Index of the H.H. Wilson Co. . . . IAI

Permission of the Department of Defense to publish this paper is acknowledged.

1953

1-53. "Review of Developments in Measurement and Specification of Surface Finish"—J. Halling; *Liverpool Engineering Society Bulletin*, v. 26, n. 6, January 1953, pp. 9, 11, 13, 15, 17, 21-31, 38.

2-53. "Tool Finishing Costs Reduced by Wet Blasting"—Eugene F. Anderson; *Tool Engineer*, v. 30, January 1953, pp. 53-54. Advantages, matte finish produced and glare reduction. Photographs. (ASM)

3-53. "Standardization of Technical Surfaces"—Willy Schenkel and Walter Schmidt; *Metalloberflache*, v. 7 ser. A, n. 1, January 1953, pp. A1-A6. DIN standard specimens are examined. Surface measurements are explained and compared with foreign standards. Symbolic representation of roughness is discussed. Tables, diagrams. (ASM)

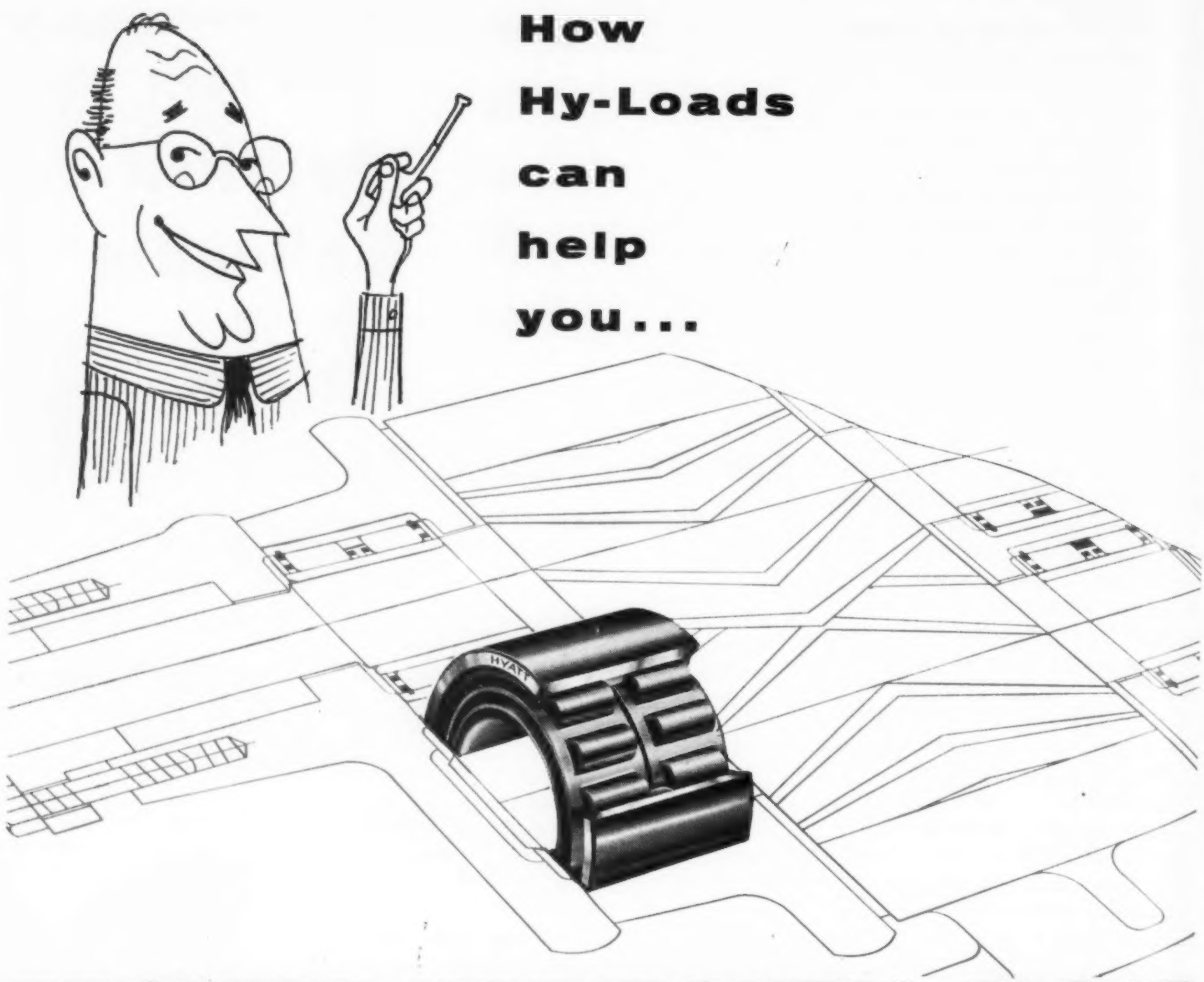
4-53. "How You Can Specify Surface Finishes"—*Steel*, v. 132, January 19, 1953, pp. 74-78. Standard terminology used by Yale and Towne Mfg. Co. for clearer understanding of surface finish specifications. Photographs and diagrams. (ASM)

5-53. "Machining, Theory and Practice"—K. G. Lewis and W. Milne; *Machinery* (London), v. 82, February 20, 1953, pp. 353-360, 367. Cutting fluid theory; factors influencing cooling requirements; effects of machining conditions, cold work and grinding on surface finishes. Graphs and diagrams. (ASM)

6-53. "Anodic and Chemical Polishing as Preparation for Electrodeposition"—B. Wullhorst; *Metalloberflache*, v. 7, n. 2, February 1953, pp. A28-A32. (In German). Polishing which removes macroscopic roughness yields surfaces of high reflective potential and supplements mechanical methods. (ASM)

7-53. "Study of Wear Surfaces with an Electron Microscope"—K. Ogawa and N. Takahashi; *Metaux Corrosion—Industries*, v. 28, n. 330, February 1953, pp. 67-74. Graphs, micrographs. 4 ref. (ASM)

8-53. "Some Methods of Measuring Surface


HYATT

Surface Finish

Topography as Applied to Stretch or Strain Markings on Metal Sheet"—W. H. L. Hooper; *Journal of the Institute of Metals*, v. 81, February 1953, pp. 161-165. Two techniques for measuring surface topography of sheet metal showing strain markings. Talysurf surface-measuring instrument, and light-interference effects are used. Macrographs. (ASM)

9-53. "Surface Measurement with Keyed Cutting Apparatus"—Walter Schmidt; *Metalloberflache*, v. 7, ser. A, n. 3, March 1953, pp. A33-A38. (In German). Surveys available machinery. Discusses DIN (German Industrial Norms) numbers. Graphs, photographs. (ASM)

10-53. "Roto-Finish, the New Mechanical Process for Trimming, Grinding, and Polishing Mass Production Articles, Part I"—H. Nann and H. A. O. Fitzler; *Metalloberflache*, v. 7, ser. B, n. 3, March 1953, pp. B41-B47. The procedure, substances for mineral grinding and polishing, and "Roto-Finish" compounds. (ASM)

11-53. "Present Status of Electrolytic and Chemical Burnishing (Polishing)"—Heinz W. Dettner; *Metall.*, v. 7, n. 9 and 10, May 1953, pp. 325-328. (In German). Economy, applicability, properties of polished surfaces, bath recipes, and special electrolytes. Photographs. 1 ref. (ASM)

12-53. "Testing and Controlling the Working Surfaces of Hollow Tools, Especially of Reducing Dies for the Production of Screws and of Drawing Dies Made of Sintered Carbide Alloys"—Werner Lueg; *Stahl und Eisen*, v. 73, n. 10, May 7, 1953, pp. 621-629. (In German). Procedure and results of tests. Spherical mirrors made inner walls accessible for perpendicular viewing. Photographs, diagrams. 24 ref. (ASM)

13-53. "New Process of Surface Finishing by Honing"—A Linek; *Metalloberflache*, v. 7, n. 5, May 1953, pp. A73-A75. (In German). New methods and equipment for finishing machine parts. Photographs. (ASM)

14-53. "Some Vibration Effects on Surfaces Produced by Turret Lathes"—P. T. Eisele and R. F. Griffin; *ASME Transactions*, v. 75, October 1953, pp. 1211-1217. Illustrations, diagrams. (IAI)

15-53. "Reflection Coefficients for Certain Rough Surfaces"—V. Twersky; *Journal of Applied Physics*, v. 24, May 1953, pp. 659-660. (IAI)

16-53. "Surface Analysis with the X-Ray Photoelectron Spectrometer"—R. G. Steinhardt Jr. and E. J. Serfass; *Analytical Chemistry*, v. 25, May 1953, pp. 697-700. Bibliography, diagrams. (IAI)

17-53. "Micro-Inch Inspection in the Timken Gage Laboratory"—Michael C. Curtis; *Machinery*, v. 59, June 1953, pp. 180-186. Surface inspection equipment. Illustrations. (ASM)

18-53. *Military Specification — Turbine, Steam, Propulsion* (For Naval Shipboard Use); MIL-T-17600 (Ships), 26 June 1953, 57 pages. Material, configuration types, components, design specifications for steam turbines for propulsion applications on U. S. Naval Ships.

19-53. "Why Don't We Standardize Surface-Plate Specs?"—R. J. Hahn; *American Machinist*, v. 97, June 8, 1953, p. 169. (IAI)

20-53. "Measuring Surface Quality in Workshop"—H. Van Dam; *Machinery* (London), v. 83, n. 2124, July 31, 1953, pp. 211-212.

21-53. *Military Specification — Turbine, Steam, General Auxiliary* (For Naval Shipboard Use). MIL-T-17523, 1 July 1953, 45 pages. Specification covers all steam turbine applications for auxiliary drives on U. S. Naval Ships. Materials, configurations, types and design requirements.

22-53. "Electropolishing" — A. T. Steer, J. K. Wilson and O. Wright; *Aircraft Production*, v. 15, July 1953, pp. 242-249. Influence on the fatigue-endurance limit of ferrous and nonferrous parts. (ASM)

23-53. "Examination of Surfaces by X-Ray Reflection"—R. H. Buteux; *Journal of the Optical Society of America*, v. 43, July 1953, p. 618. Examples. Photomicrographs. (ASM)

24-53. "New Instrument for Roughness Measurement"—A. F. Underwood and J. B. Bidwell; *Machine and Tool Blue Book*, v. 49, July 1953, pp. 202-204, 206, 208-210, 212-215. Instrument which is compact, easy to use, and accurate. Diagrams, photographs. (ASM)

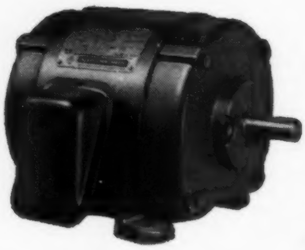
(*Continued on Page* 338)

EIGHT WAYS TO GET VARIABLE SPEED

Mechanical

Where moderate speed range is required and where machine may be stopped to make speed changes. Horsepower range—1½ to 300. Speed adjustment range—9 to 28 percent. Two *Vari-Pitch* sheaves used together double range of adjustment.

Combination starter



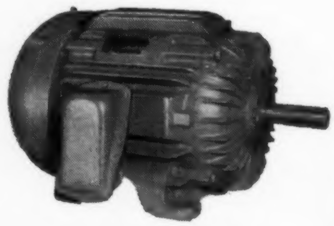
Squirrel-cage motor

Vari-Pitch stationary control drive

Mechanical

Where infrequent change of speed in low horsepower drives is required and machine may be stopped for speed adjustment. Especially suitable for fan drives, stokers, small pumps and tools. Horsepower range—fractional to 4 hp. Speed adjustment range—18 to 50 percent. Use of two adjustable sheaves doubles speed adjustment range.

Across-the-line starter

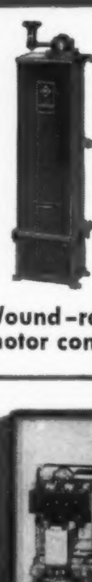


Squirrel-cage motor

Texrope adjustable drive

Electrical

Where stepped speed control is satisfactory. Available with stepless control in larger sizes by using liquid rheostat. Speed is varied by means of control on secondary windings of motor. Horsepower range—5 hp and up. Speed adjustment range—50 percent of synchronous speed to full load speed.



Wound-rotor motor control

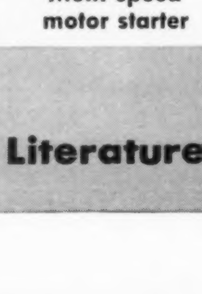
Wound-rotor motor

Texrope V-belt drive

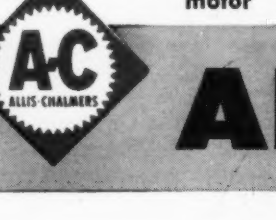
Electrical

Where a few definite speeds are required. Up to four speeds available from one motor. Motor is built on standard squirrel-cage frame with special windings and control. Furnished for variable torque, constant torque and constant horsepower. Horsepower range—½ hp up.

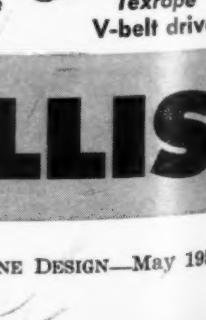
Texrope and Vari-Pitch are Allis-Chalmers trademarks.



Multi-speed motor starter



Multi-speed squirrel-cage motor



Texrope V-belt drive

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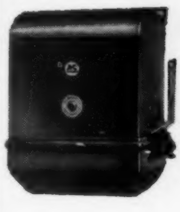
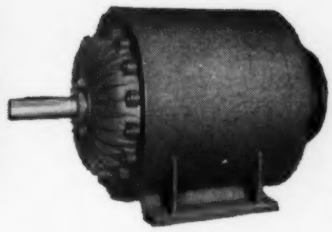
Mechanical

Where speed must be changed while machine is in motion. Particularly good for machines requiring fine adjustment while operating. Double range of adjustment may be obtained by using two *Vari-Pitch* sheaves. Horsepower range—1½ to 600. Speed adjustment range—9 to 28 percent with one *Vari-Pitch* sheave.



Reduced voltage starter



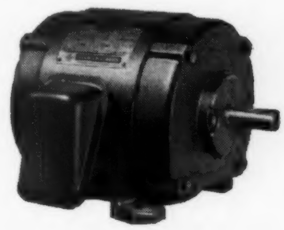
Squirrel-cage motor

***Vari-Pitch* motion control drive**

Mechanical

Where very wide range speed control is required or where enclosed unit is desired. May be manually or remotely controlled. Motor may be mounted on speed changer housing for compact installation. Horsepower range—1½ to 75. Speed adjustment range—3¾ to 1.

Across-the-line starter



Squirrel-cage motor

***Vari-Pitch* speed changer**

ALLIS-CHALMERS
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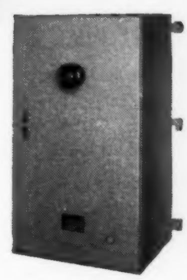
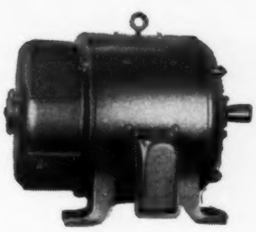
from One Reliable Source

Electrical

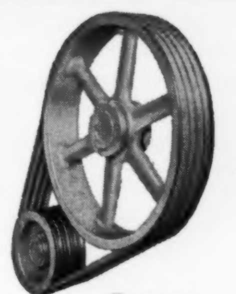
Where great versatility is required. Speed may be varied by various types of control, either stepped or stepless. For both constant and variable torque loads. Horsepower range—½ hp up. Speed adjustment range—zero to maximum speed. Maximum speed in smaller sizes, 3500 rpm.



Direct current control



Direct current motor

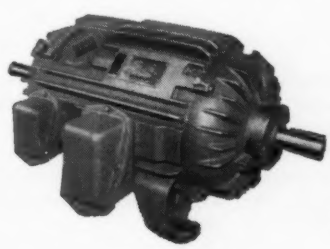


***Texrope* V-belt drive**

Combination

Where extremely wide range is required, a combination drive adds the speed control range of the motor to that of the *Vari-Pitch* drive. Hundreds of combinations of any of the above units can be worked out to fit the requirements of a particular design.

Wound-rotor motor control



Wound-rotor motor

***Vari-Pitch* motion control drive**

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Surface Finish

(*Continued from Page* 335)

25-53. "Surface Testing with the Interference Microscope"—W. Illig; *Metalloberflache*, Ausgabe A, v. 7, n. 7, July 1953, pp. 97-104. (In German). Principle of the interference method and how to evaluate resulting recordings. Diagrams, photographs. (ASM)

26-53. "Electrolytic Grinding"—R. H. Waring; *Machinery Lloyd* (overseas ed.), v. 25, August 29, 1953, pp. 68-70. Process and its advantages. Diagrams. (ASM)

27-53. "The Electro Erosion Process"—J. L. Adcock; *Machinery* (London), v. 83, August 21, 1953, pp. 355-359. Electrolytic, electro-arcing and electrosparking methods for cutting metals. Photographs.

28-53. "Mechanical Pumps For High-Temperature Liquid Metal"—P. M. Clark; *Mechanical Engineering*, v. 75, n. 8, August 1953, pp. 615-618. In the development of nuclear power for submarines a relatively large heat-transfer test system using liquid sodium and potassium and liquid sodium as heat transfer media was necessary. Centrifugal pumps of 600 gpm capacity were built to pump liquid metal at 750 F. Seals on pump shaft presented problems. Rotary face seals reduced leakage rates from 10 to less than 0.1-cu ft per hr. Surface finish on seal elements, wear rings was critical. Most wear rings averaged about 1 mu in. or less. A surface measuring over 2 mu in. was rejected.

29-53. "An Interferometer for Examining Polished Surfaces"—Ronald F. Sugg; *Mechanical Engineering*, v. 75, August 1953, pp. 629-631. Paper presented at the Spring Meeting of the ASME, Columbus, O., April 28-30, 1953. Portable multiple-beam interferometer for use wherever the examination of fine surface detail is required. Diagrams. (ASM)

30-53. "Surface; Test Cut Machine Cost"—R. M. Lorz; *Iron Age*, v. 172, n. 8, August 20, 1953, p. 63. (IAI)

31-53. "Geometrical Considerations Arising from Use of Square Wave Calibration Standard of Surface Finish"—N. J. Peres; *Australian Journal of Applied Science*, v. 4, n. 3, September 1953, pp. 380-387.

32-53. "Measuring Surface Roughness"—*Can Metals;* v. 16, n. 11, October 1953, pp. 66-67.

33-53. "Measurement of Superimposed Surface Finishes"—R. E. Carroll and N. Gortz; American Society of Mechanical Engineers, Paper No. 53-F-29. Presented meeting October 5-7, 1953.

34-53. "Theory and Practice of Chemical Polishing, Part I, Chemical Processes for Copper-Base Alloys"—R. Pinner; *Electroplating and Metal Finishing*, v. 6, October 1953, pp. 360-367. Chemical polishing compared to and contrasted with electropolishing and mechanical polishing. Refers to an unpublished method for copper-based alloys and nickel with certain advantages over the Battelle process. Other new work. Table, graphs. (ASM)

35-53. "Wear of Carbide Tools—Its Effect on Surface Finish and Dimensional Accuracy"—A. J. Pekelharing and R. A. Schuermann; *Tool Engineering*, v. 31, October 1953, pp. 51-57. Results of various machining operations on parts of typical steels using singlepoint carbide tools. Diagrams, charts. 3 ref. (ASM)

36-53. "Porosity of Electrodeposited Metals, Part XII, Measurement of Surface Roughness and Its Change in Exposure"—Thon, Ling Yang and Stella Yang; *Plating*, v. 40, October 1953, pp. 1135-1137. Method of obtaining true specific area of solid. Diagrams. 2 ref. (ASM)

37-53. "Measuring Surface Roughness"—*Canadian Metals*, v. 16, October 1953, pp. 66-67. Electronic roughness tester, particularly suitable for workshop, which can be used for the above against chosen standards. Table, diagram. (ASM)

38-53. "Movable-Anode Tube Gages Surface Roughness"—Joseph B. Bidwell; *Electronics*, v. 26, November 1953, pp. 181-183. Unit adaptable to wide range of surfaces. High electrical output of tube reduces complexity of amplifying and indicating circuits. Diagrams, graphs, photographs. (ASM)

39-53. "Method for Recording Roughness of Submerged Surfaces"—John W. Sawyer; *Journal of the American Society of Naval Engineers Inc.*, v. 65, n. 4, November 1953, pp. 816-820. Developed technique for forming three-dimensional rigid negative replicas of

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Measuring 26 inches wide, 49 inches long, and 2½ inches at its deepest part, this refrigerator inner door panel typifies the large-sized, tough products that can be vacuum-formed from BAKELITE High-Impact Styrene TGD-5001. It was produced by **General American Transportation Co.**, Chicago, Ill.

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submerged surfaces. Method consists of casting a thermosetting resin onto the submerged surface to be inspected. Replica can be removed and studied. Tank wall surfaces, pipes, propellers, ships' hulls may be inspected.

40-53. "ASA Will Simplify Surface Roughness Measurements"—F. W. Witzke; *Iron Age*, v. 172, n. 23, December 3, 1953, pp. 180-182. Proposed revision of ASA Standard B46-1953 should result in change from root-mean-square (rms) to arithmetic average microinch readings. Generally this will assure greater accuracy of roughness measurements. Specifications for measuring instruments, such as force required to move stylus not to exceed 2½ grams, are specified. Roughness comparators will permit more accurate calibration of instruments. Effects of adopting new standard: all finishes will be read in arithmetic average microinches; instruments now in use need to be calibrated.

41-53. "New York Academy of Sciences' Conference on Properties of Surfaces"—*Chemical and Engineering News*, v. 31, November 16, 1953, pp. 4767-4768. Abstract of papers. (IAI)

42-53. "Some Analyses on the Electropolished Surface"—Fusao Hayama; *Castings Research Laboratory Report*, No. 4, 1953, pp. 52-54. Compares luster of electropolished and mechanically finished surfaces. Graphs, tables, diagram. (ASM)

43-53. *Properties of Metallic Surfaces*—Institute of Metals, London, England. 355 pages. Symposium held by the Metal Physics Committee of Institute of Metals. Discusses 13 papers showing importance of surface finish as contributing to strength, service performance and life of a metal component. Includes: "Specialized Microscopical Techniques in Metallurgy," S. Tolansky; "Radioisotopes in the Study of Metal Surface Reaction in Solutions," M. T. Simnad; "Influence of Machining and Grinding Methods on the Mechanical and Physical Condition of Metal Surfaces," Peter Spear, Ian R. Robinson and K. J. B. Wolfe; "Effect of Lubrication and Nature of Superficial Layer After Prolonged Periods of Running," F. T. Barwell; "Crystalline Character of Abraded Surfaces," P. Gay and P. B. Hirsch; "Effect of Surface Conditions on the Mechanical Properties of Metals, Mainly Single Crystals," E. N. da C. Andrade; "Effect of Surface Condition on the Strength of Brittle Materials," G. C. Gurney; "Influence of Surface Condition on the Strength of Steel," R. J. Love; "Influence of Surface Films on the Friction and Deformation of Surfaces," F. P. Bowden and D. Tabor; "Diffusion Coatings," D. M. Dovey, I. Jenkins and K. C. Randall; "Nature and Properties of the Anodic Film on Aluminum and Its Alloys," H. W. L. Phillips; "Chemical Behavior as Influenced by Surface Conditions," U. R. Evans; "Effect of Method of Preparation on the High-Frequency Surface Resistance of Metals," R. G. Chambers and A. B. Pippard. (ASM)

44-53. "An Imprint Method of Viewing Rough Surfaces Under the Electron Microscope"—Hermann Pfisterer; ***Naturwissenschaften***, v. 40, n. 3, 1953, p. 106. (In German). Method. Electron micrographs. 4 ref. (ASM)

45-53. "Surface-Finish Control—SAE Recommended Practice"—***SAE Handbook***, 1953, pp. 186-188. Roughness comparison specimens are well adapted for use by designers and draftsmen. Provide means for production control of finishes. Steps for control of surface finish are outlined.

46-53. "Surface Finish" — SAE Standard: ***SAE Handbook***, 1953, pp. 184-185. Technical committee report on surface finish approved March 1949 and last revised January 1952. SAE standard in general agreement with American Standard for Surface Roughness, Waviness and Lay, B46.1-1947 and ASA for Physical Specimens of Surface Roughness and Lay ASA B46.2-1952, Part 1.

47-53. "A Review of the Developments in the Measurement and Specification of Surface Finish"—J. Hallig; ***Transactions of the Liverpool Engineering Society***, v. L-XXIV, 1953, pp. 65-91. The engineering aspects of surface finish are reviewed in four parts: (1) Functional problems showing variation in surface finish requirements; (2) Production problems including methods of production, need for new processes, factors influencing roughness and physical conditions of machined surfaces, materials, tools, machine tools, operating conditions, coolants; (3) Specification problems. (4) Measurement problem. Nature of machined surfaces reviewed. Methods of measurements and specification include: optical, Zeiss-Smaltz surface finish microscope, Visual comparator, straightedge shadow, taper sectioning, surface finish parameters, Tomlinson micro finish re-

corder, Topograph, Abbot Profilometer, Talysurf, Brush surface analyzer, Phillips roughness tester type PR 9150, Tomlinson waviness recorder, the Talyrond.

48-53. "Approach to the Evaluation of Coated Paper Smoothness"—L. J. Scheid and A. H. Hupp; *Tappi*, v. 36, October 1953, Sup. pp. 177A-178A. Bibliography, illustrations. (IAI)

1952

1-52. "Wheel Dressing for Form Grinding" —*Machinery* (London), v. 80, n. 2042, January 1952, pp. 18-22.

2-52. "Making Finishing Compositions"—L. R. Eastman; *Plating*, v. 39, n. 1, January 1952, pp. 47-49. Analysis of new equipment and methods and discussion of composition developed in laboratory in solving polishing and buffing problems.

3-52. "The Mechanical Surface Finishing of Metals"—G. T. Colgate; *Sheet Metal Industries*, v. 29, January 1952, pp. 71-78, 82; February 1952, pp. 163-172. First installment of a series in which the methods considered will form part of a sequence, the final stage of which is electrodeposition, coloring, or some other form of chemical or electrochemical treatment such as anodizing. Part 1: Polishing. Part 2: The effect of various factors on ease of polishing. (ASM)

4-52. "Metal Surface Phenomena"—Herbert H. Uhlig; *Metal Interfaces*, American Society for Metals, 1952, pp. 312-335. A fundamental discussion of physical and chemical forces acting at the surface of metals. Adsorption on metals; physical adsorption and chemisorption, chemisorption of oxygen on tungsten; passivity of oxygen on tungsten; passivity; adsorption and lubrication; adsorption of metals on metals; and factors affecting chemisorption. Diagrams and graphs show illustrative data for various metals. (ASM)

5-52. "Surface Finish" — SAE Standard; *SAE Handbook*, 1952, pp. 178-180. Technical committee report on surface finish approved March 1949 and last revised January 1952. SAE Standard in general agreement with American Standard for Surface Roughness, Waviness and Lay, B46.1-1947 and ASA for Physical Specimens of Surface Roughness and Lay ASA B46.2-1951, Part 1.

6-52. "Surface Finish Committee" — *SAE Handbook*, 1952, p.29. Membership of SAE Surface Finish Committee.

7-52. *Schleif Industrie Kalender* (Handbook of the Grinding Industry) Ed. 25—W. Classen; Vulcan Verlag, Wiessenstrasse 55, Essen, Germany, 1952, 528 pages. Natural and synthetic grinding polishing agents; equipment, methods and procedures for grinding metals, wood, and stone; physical properties and standards of grinding and polishing agents, tradenames and other pertinent information. (ASM)

8-52. *Design and Use of Cutting Tools*—Leo J. St. Clair; McGraw-Hill Book Co. Inc., New York, 1952, 421 pages. Design, selection and use of cutting tools. Surface finish discussed as relating to built-up edge on cutting tool, feed per revolution, side rake, chip flow, surface speeds, small flats, and stoning of cutting tools. Ideas for increasing tool life.

9-52. *The Science of Precision Measurement* —DoAll Co., Des Plaines, Ill., 256 pages. Interprets the nationally and internationally accepted lineal standard of measurement by giving instruction and showing its practical application to production and inspection of manufactured parts. Discusses accuracy necessary to control thousandths-inch production tolerances, and practical procedures in utilizing instruments such as gage blocks and gaging instruments. A new method using optical flats and a "visible scale" to determine surface flatness, finish, parallelism is introduced. Procedures are recommended for statistical sampling of parts for dimensional quality control. Mobile inspection systems. (ASM)

10-52. "Physical Specimens of Surface Roughness and Lay"—American Standards Association, American Standard B46.2-1952. Published by American Society of Mechanical Engineers, New York. Specifications given for two types of physical surface roughness and lay specimens. One type, precision reference specimen, is designed to serve as a calibration specimen of surface roughness height and includes surface contour, material accuracy uniformity; other covers surface roughness comparison specimens for visual and tactual use.

11-52. *Precision Measurement in the Metal*

Surface Finish

Working Industry—Dept. of Education of International Business Machines Corp., Syracuse University Press, 1952, 365 pages. Chapters deal with line-graduated instruments; precision gage blocks, plug, ring, snap-thread, and dial gages; test indicators; micrometers; verniers; surface plates and accessories; angle measuring instruments; comparators; optical instruments and surface finish measurement; measuring machines, hardness testers; and nondestructive testing methods. (ASM)

12-52. "Electrolytic Polishing; a Process for Treating Stainless Steels and Irons"—*Automotive Engineer*, v. 42, February 1952, p. 56. In the Electropol process, the work is the anode. When current is passed, metal is removed from the outer surface of the work. Applications. (ASM)

13-52. "Barrel Finishing"—*Metal Industry*, v. 80, February 8, 1952, pp. 105-107. Various types of machines used. (ASM)

14-52. "Measurement of Lustre as a Method of Evaluating Metallic Surfaces"—Joh. Elze and H. Gruss; *Metalloberflache*, ser. A, v. 6, February 1952, pp. A17-A23. (In German). Instrument measures strictly directed reflection, reflection within a selected range of dispersion angle and astigmatism of dispersion. Diagrams, photographs, graphs, photomicrographs, and tables. (ASM)

15-52. "Power Brush Finishing"—V. K. Charvat and R. C. Sasena; MACHINE DESIGN, v. 24, n. 2, February 1952, pp. 112-121. Application of power-driven brushes to obtain unusual or more refined surface finishes. Includes a table of design factors for brushes and brushing machines. (ASM)

16-52. "Barrel Finishing, Part II, Selection of Equipment"—Morris S. Shipley; *Plating*, v. 39, March 1952, pp. 257-260. Points to consider in equipping a barrel-finish department for efficient operation. (ASM)

17-52. "Smooth Finish for Strip . . . Moving Abrasive Produces It"—S. L. Johnson and R. G. Hall; *Steel*, v. 130, n. 9, March 3, 1952, pp. 82-83. How coated abrasive paper progressively fed over moving steel strip produces variety of finishes, cleans, and scours both surfaces simultaneously. (ASM)

18-52. "Application of the Electron Microscope to Measurement of Specific Surfaces. Determination of the Effectiveness of Grinding." Rene Bernard, Emile Pernaux and Stanislas Teichner; *Journal de Chimie Physique et de Physico—Chimie biologique*, v. 49, March 1952, pp. 147-156. (In French). Factors influencing above measurements. Tables and graphs. 24 ref. (ASM)

19-52. "The Opaque-Stop Microscope as a Means of Studying Surface Relief"—W. M. Lomer and P. L. Pratt; *Journal of the Institute of Metals*, v. 80, March 1952, pp. 409-411. Some results obtained by the above methods as applied to metallic and nonmetallic surfaces. (ASM)

20-52. "A High-Resolution Surface-Profile Microscope"—S. Tolansky; *Nature*, v. 169, March 15, 1952, pp. 445-446. Describes improvements made by reversing the illumination, using a bright field crossed by a dark line, instead of a light slit on a dark field. (ASM)

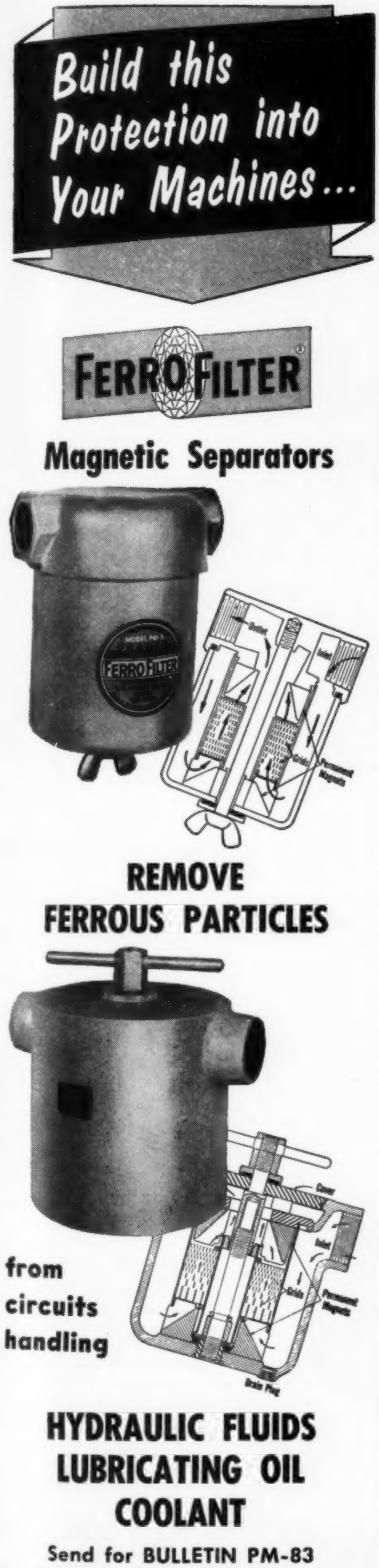
21-52. "Electrolytic Grinding: Stubborn Alloys Less Formidable"—George Keeleric; *Steel*, v. 130, n. 11, March 17, 1952, pp. 84-86. The principles of removing stock by electrochemical action are applied successfully to the grinding of difficult-to-machine metals and metal carbides. Surface finish is excellent. (ASM)

22-52. "Arc Machining Makes Hard-to-Cut Jobs Easy"—H. V. Harding and V. E. Matulaitis; *American Machinist*, v. 96, n. 4, March 1952, pp. 136-141. Arc machining method discussed. Hard-to-machine materials can be machilled by broken-tap "disintegrator". Finish is controlled by varying rate of metal removal. Finishes down to 2-4 mu in. are obtainable.

23-52. "Carbide Bur at 90,000 rpm Finishes Exact R. 63 Bores"—E. J. Tangerman; *American Machinist*, v. 96, n. 4, March 1952, pp. 142-144. Ball bearing inner races are ground to 4-6 mu in. by carbide-tipped bur.

24-52. "A New Method for Surface Flaw Detection"—*Industry & Welding*, v. 25, April 1952, pp. 79-80. The Faxfilm process in which exact reverse replica of a test surface is quickly made in clear plastic. Projection of this replica in a microprojector provides a magnified representation of the surface, with marked three-dimensional effect. (ASM)

25-52. "A ght-Profile Microscope for Surface Studies' 'eitschrift fur Electrochemie;



Berichte der Bunsengesellschaft fur Physikalische Chemie, v. 56, April 1952, pp. 263-267; disc. p. 267. (In English). New microscope technique which permits rapid study of topography of metal and crystal surfaces. The technique is a development of the familiar Schmaltz light-cut method and gives profile magnification of up to 2000 X with resolution of the order of 0.25 micron. The method gives topography over a complete area with a single photograph and is easy to use. It is recommended for use for structures which are too coarse for precision interferometry. (ASM)

26-52. "Fine Crystals at Polished Surfaces"—Bruce Chalmers; *Metal Progress*, v. 61, May 1952, pp. 94-95. Further evidence that mechanical polishing leaves behind a surface which, in crystallographic nature, may be far different from the metal a small distance underneath. Lave photographs of silver single crystals. (ASM)

27-52. "Machining Magnesium Alloys"—*Magazine of Magnesium*, May 1952, pp. 10-15. Advantages over other commercially used metals include high machine speeds, low power requirements, minimum tool wear, and smooth finish. 30 pages of tabular data and recommended tool design for the machining of magnesium. (ASM)

28-52. "Finishing Methods for Precision Metal Molding"—*Precision Metal Molding*, v. 10, n. 6, June 1952, pp. 45-56, 68-74.

29-52. "Surface Areas of Metals and Metal Compounds; Rapid Method of Determination"—C. Orr Jr., H. G. Blocker and S. L. Craig; *Journal of Metals*, v. 4, n. 6, June 1952, pp. 657-660.

30-52. "Surface Treatment for Saving and Substitution of Materials"—H. Wiegard; 4th International Mechanical Engineering Congress, June 1952, 4 pages. Classifies surface treatments and gives numerous brief examples or suggestions for their use. Includes mechanical, chemical, electrochemical, and diffusion processes and coating with metallic and nonmetallic layers. Metals mentioned include carbon, alloy, and stainless steels, aluminum alloys, stellites, zinc, and chromium. Tabular data on influence of thread production and surface quality of thread on tensile fatigue strength of screws; and fatigue strength of piston pins, case hardened on all sides—for low alloy and C steels. (ASM)

31-52. "Surface Finish"—P. E. Dyachenko; *Industrial Diamond Review*, new ser., v. 12, June 1952, pp. 111-114. (Reprinted from *Courrier de la Normalisation*, v. 16 (87), 1949, pp. 279-283.) Survey of Russian apparatus and procedures for surface-finish measurements. Diagrams, graphs, and illustrations. (ASM)

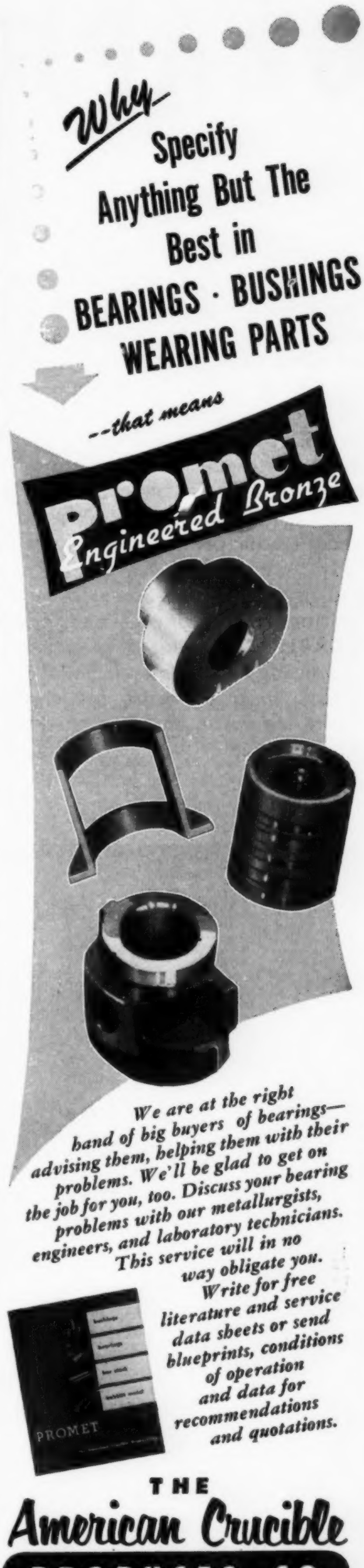
32-52. "The Effect of Diamond Wheel Grinding on the Surface Finish of Sintered Carbides"—E. Dinglineer; *Engineer's Digest*, v. 13, June 1952, pp. 189-193. (Translated and condensed from *Werkstattstechnik und Maschinenbau*, v. 42, February 1952, pp. 50-56.) In order to reach sound conclusions from metal-cutting research, many variables, including tool angles, cutting speeds and feeds, cooling and heating must be taken into account. An additional variable which, if not controlled, can completely vitiate research results, is keenness and surface finish of the cutting tool. This was first established in machining tests on wood, plastics, and other similar materials; it was also found that the optimum finish was not necessarily the finest. It appears that various materials require varying grades of tool finish for most satisfactory machining. Data tabulated and charted. (ASM)

33-52. "Electro-Polishing and Material"—Joseph Heyes; 4th International Mechanical Engineering Congress, June 1952, 8 pages. A survey aimed at drawing attention to the advantages of electropolishing. Test results in relation to fatigue, crystal structure, corrosion, light reflection, and friction and wear. Materials are steel and aluminum. Table, photographs and graphs. 11 ref. (ASM)

34-52. "Surface Finish—Its Effect on Wear"—C. R. Lewis; *SAE Journal*, v. 60, n. 6, June 1952, pp. 57-60. Method of wear reviewed. Rougher parts generally wear at greater rate. However, under certain conditions smoother parts can have greater wear rates. Optimum roughness is determined only by experiment or experience.

35-52. "Finishing Methods for Precision Metal Moldings"—*Precision Metal Molding*, v. 10, n. 6, June 1952, pp. 45-56, 68-74. Die, investment, permanent mold, plaster mold casting and powder metal parts. Finishing of

(*Continued on Page* 350)



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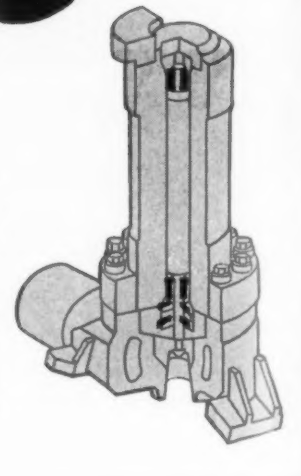

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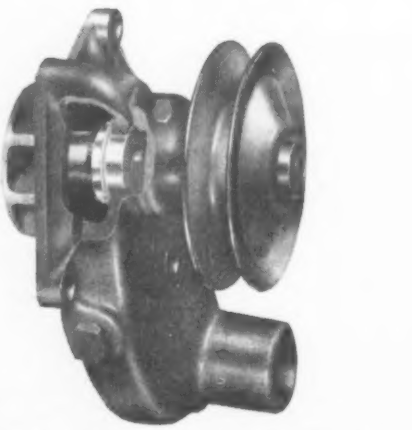

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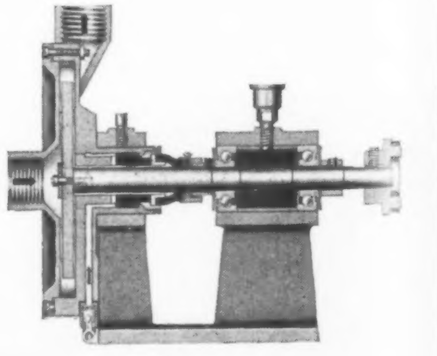

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OUR 101ST YEAR

THE UNITED STATES

Surface Finish

(*Continued from Page* 347)

dies by abrasive belt, abrasive blast, barrel finishing, polishing and buffing, chemical cleaning, organic finishing, chemical protective treatments, and plating.

36-52. "New Precision Reference Specimens for Surface Finish Control"—C. R. Lewis and A. F. Underwood; *Tool Engineer*, v. 29, July 1952, pp. 36-40. Development of a method of standardization of production and distribution of accurate and reproducible physical standards of surface roughness. Design and machining of specimens. Diagrams and photographs. (ASM)

37-52. "Processing and Measuring Methods in the Surface-Finishing Industry"—J. Ickert; *Zeitschrift des Vereines Deutscher Ingenieure*, v. 94, July 1, 1952, pp. 663-665. Equipment for electroplating, paint application, roughness and hardness measurement, and automatic flame hardening. 19 ref. (ASM)

38-52. "Optical Determination of Quality of Metallic Surfaces"—J. Elze and H. Gruess; *Engineers' Digest*, v. 13, n. 7, July 1952, pp. 211-212. Roughness of metal surface is determined by measuring amount of reflected light within a stray cone of chosen apex angle about axis of reflected ray.

39-52. "The Influence of Higher Rake Angles on Performance in Milling"—Joe H. Crawford and M. Eugene Merchant; *Machinery* (London.), v. 81, July 10, 1952, pp. 47-55. A range of rake angles and cutting speeds was selected, and studies made on cutter life and surface finish as a function of these variables. Effect of these variables on such quantities as forces, shear angle, chip friction work done in cutting, and calculated temperature of the chip-tool interface. Photographs, graphs and table. (ASM)

40-52. "Micro-Interferometry for Surface Measurements"—R. E. Sugg; *Product Engineering*, v. 23, August 1952, pp. 156-157. Equipment, procedures, and typical results. Comparative photomicrographs and interferograms. (ASM)

41-52. "Structure of Metal Surfaces (According to New Investigations by Electron Beams)"—H. Raether; *Metalloberflache*, sec. A, v. 6, August 1952, pp. A113-A119. (In German). The mechanism of surface analysis by means of electron beams. Results of the investigation on mechanically and electrolytically polished metal surfaces. Electron micrographs and diffraction patterns. (ASM)

42-52. "How to Check Quality of Surface Finish"—*Standardization*, v. 23, n. 8, August 1952, pp. 228-229. Need for selecting correct finish for the right job is emphasized. New American Standard, "Physical Specimens of Surface Roughness and Lay," B 46.2-1952, is reviewed briefly.

43-52. "The 'Why' of Surface Finish Standards"—James A. Broadston; *Standardization*, v. 23, n. 8, August 1952, pp. 230-234. Need for standards and development of present ASA Standard B 46.2-1952 outlined. Definitions, illustrations and types of machine finishes given. Instruments and methods.

44-52. "The Use of Standard Roughness Comparator Specimens"—Donald R. Williamson; *Standardization*, v. 23, n. 8, August 1952, pp. 235-237. Methods of determining surface roughness include tactual comparison and instrument measurement. Tactual comparison utilizes roughness comparison specimens. Design, setup (the most economical machine method for producing desired finish), production and inspection.

45-52. "The 'Gold Standard' Precision Specimens of Surface Roughness"—C. R. Lewis; *Standardization*, v. 23, n. 8, August 1952, pp. 238-242. Early attempts made 20 years ago to specify surface finish. Mechanical methods for measuring finish have limitations. Joint research project between Chrysler Corp. and General Motors Corp. resulted in development of series of physical specimens with definite geometric patterns. These specimens included 18 surfaces ranging from 5 mu in. average deviation from the mean to 500 mu in. Only 5 specimens are now commercially available. Original specimens produced in gold by special machine built by G-M Research Lab. Div. Replicas were made from the gold masters. Replicas now available include 20, 32, 50, 80 and 125 mu in.

46-52. "Application of Profilometer to the Study of Structural Corrosion"—O. G. Deriagina and G. V. Akimov; *Doklady Akademii Nauk SSSR*, v. 85, new ser. n. 6, August 21, 1952, pp. 1305-1308. Changes of surfaces were investigated on zinc, aluminum, iron and their alloys. (ASM)

47-52. "Pneumatic Gauging Applied to the

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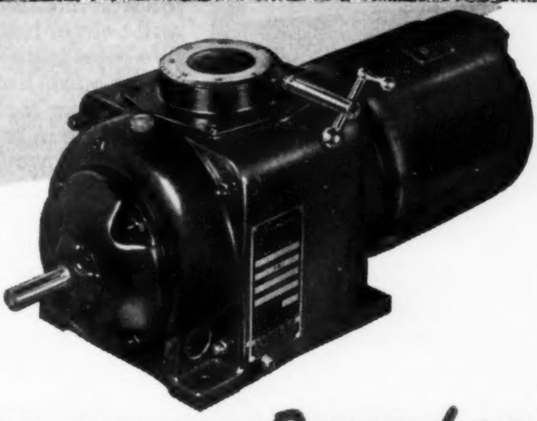

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Surface Finish

Measurement of Surface Finish"—M. Graneek and H. L. Wunsch; *Engineer*, v. 194, September 1952, pp. 387-389. Details of a special design of measuring jet suitable for examination of both flat and cylindrical surfaces. Results obtained with pneumatic comparator on a series of ground and turned surfaces having different grades of finish showed that a reasonable linear relation existed between corresponding centerline average readings. (ASM)

48-52. "Review of Surface Finish Literature"—John W. Sawyer, MACHINE DESIGN, v. 24, n. 9, September 1952, pp. 147, 290, 292, 294, 296, 298, 301, 302, 305, 306; v. 24, n. 10, October 1952, pp. 328, 331, 332, 334, 336, 338, 340, 342, 344, 346, 348; v. 24, n. 11, November 1952, pp. 286, 288, 290, 292, 294. Published literature on surface finish has been compiled into a bibliography covering period 1945—1951 inclusive. Includes about 220 separate abstracts in Parts 1 and 2. Detailed subject index of abstracts comprises Part 3.

49-52. "An Electrical Roughness Tester for the Workshop"—G. W. Van Santer; *Phillips Technical Review*, v. 14, September-October 1952, pp. 80-86. Instrument consists of two pickups, one amplifier, a rectifier, and a moving-coil meter. (ASM)

50-52. "Establishing of the Surface Quality in Turning from the Weight of Shavings"—W. Leyensetter; *Zeitschrift des Vereines Deutscher Ingenieure*, v. 94, September 1, 1952, pp. 825-838. (In German). Experimental details on a new method. Data are tabulated and charted. (ASM)

51-52. "The Mechanical Surface Finishing of Metals"—G. T. Colgate; *Sheet Metal Industries*, v. 29, October 1952, pp. 941-948. Polishing the specific metals, steel, cast iron, stainless steel, magnesium alloys, Monel, aluminum, nickel silver, solid nickel, copper, brass stampings, zinc-base die castings, and Britannia metal and pewter. Polishing electrodeposits is included. (ASM)

52-52. "New Lubricant Improves Die Life and Finish"—W. E. Curtiss; *Iron Age*, v. 170, October 30, 1952, pp. 94-95. In drawing a 6.5-in. deep, 3-in. diameter shell from 0.065 annealed blanks of 1010 steel, considerable difficulty was encountered in fourth and final draw. Hard chromium plated dies had extremely short life, and pick-up on dies caused scuffing and scratches on shells. Use of Metalloid X-60 as a die lubricant increased number of pieces per dressing from 1000 to 11,800 with same dies. Improved surface finish and increased output were achieved with no changes in setup, feeds, speeds, and lubrication methods. (ASM)

53-52. "Surface Testing with Micro-Interferences—A New Surface Interferometer"—Rudolph Landwehr; *Zeitschrift fur Angewandte Physik*, v. 4, October 1952, pp. 377-386. Describes and diagrams apparatus. Reflecting control surfaces are extended and moved under a microscope along with the specimen. Examples of application. 31 ref. (ASM)

54-52. "Determination of the True Specific Surface of Hard Dispersoids by Air Permeability"—T. A. Zavaritskaia and V. N. Grigarov; *Doklady Akademii Nauk SSSR*, v. 86, new ser. n. 4, October 1, 1952, pp. 757-758. (In Russian). Data on aluminum and polystyrol powders. Tables. 3 ref. (ASM)

55-52. "A Non-Electrolytic Smoothing Treatment for Steel"—W. A. Marshall; *Metal Finishing*, v. 50, November 1952, pp. 78-83; December 1952, pp. 67-69. Part I: Method for smoothing and etching steel samples for metallographic examination. It has potential use for etching steel articles without destroying polish prior to decorative plating. Tables, diagrams, and micrographs. Part II: Adhesion of electrodeposited nickel to treated ferrous metals. (ASM)

56-52. "How to Grind Titanium"—Leo P. Tarasov; *American Machinist*, v. 96, November 1952, pp. 135-146. Grinding fluids, wheel specifications, rates of cut, titanium variables, surface finish, and abrasives recommended. Tables, graphs, and photographs. (ASM)

57-52. "Recent Developments in Naval Propulsion Gears"—Cdr. Ivan Monk, U. S. N.; Lieut. Cdr. L. I. Thomas, and C. C. Atkinson. Paper n. 6 presented at Annual Meeting Naval Architects, November 13-14, 1952, New York. Details of extensive tests conducted on full-size naval propulsion gears at U. S. Naval Boiler and Turbine Laboratory. Developmental gears include hobbed, shaved, lapped, carburized and ground.

58-52. "Determination of Surface Geometry and Structure by Microscopy and Diffraction"—C. F. Tuffs; *Analytical Chemistry*, v. 24,

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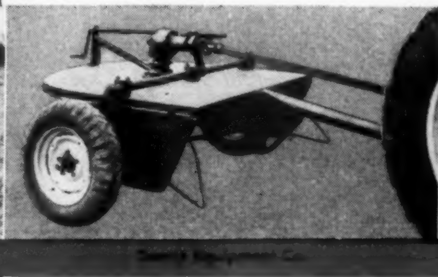

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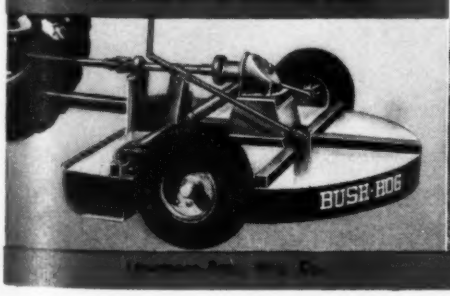

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Surface Finish

November 1952, pp. 1700-1704. (IAI)

59-52. "Direct Examination of Solid Surfaces Using Commercial Electron Microscope in Reflection"—J. W. Menter; *Journal of the Institute of Metals*, v. 81, Part 3, November 1952, pp. 163-167.

60-52. "Symposium on Properties of Metallic Surfaces"—*Engineering*, v. 174, n. 4531, 4533, 4534. November 1952.

61-52. "Abrasive Tumbling Offers Finishing Economics"—Allen G. Gray; *Product Finishing*, v. 17, November 1952, pp. 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88. Application at General Electric's West Lynn Meter and Instrument Works for finishing of numerous small parts. Abrasive tumbling, rolling, burnishing, barrel finishing with aluminum oxide and application to zinc die casting and steel stampings. (ASM)

62-52. "Gear Measuring Equipment used by the Bureau of Ships, U. S. Navy"—John W. Sawyer; *Journal of the American Society of Naval Engineers*, v. 64, November 1952, pp. 719-731. Instruments now used for gear inspection at the Naval Boiler and Turbine Laboratory, Philadelphia, and the Engineering Experiment Station, Annapolis. (ASM)

63-52. "Direct Examination of Solid Surfaces Using a Commercial Electron Microscope in Reflection"—J. W. Menter; *Journal of the Institute of Metals*, v. 81, November 1952, pp. 163-167. Modifications necessary for conversion of Metropolitan Vickers E M3 electron microscope for use in direct examination of solid surfaces by reflection. Diagrams and micrographs. 14 ref. (ASM)

64-52. "Gloss Evaluation of Materials"—R. S. Hunter; *ASTM Bulletin*, n. 186, December 1952, pp. 48-55.

65-52. "Electron Diffraction Investigation of Polished Surfaces"—T. S. Renzema; *Journal of Applied Physics*, v. 23, December 1952, p. 1412. (IAI)

66-52. "Some Practical Aspects of Specifying Surface Finish"—Joseph Adilletta; *Product Engineering*, v. 23, December 1952, pp. 150-154. Typical surface conditions of parts prepared by various machining methods and standard designations for them. (ASM)

67-52. "Electron Microscope Investigation of Metal Surfaces, Part II, Adaptations for Metal Research"—D. A. Beekhuis and J. A. Seuchmann; *Metalen*, v. 7, December 31, 1952, pp. 444-458. Results of electron microscope in wear tests and on concrete reinforcing wire. 25 ref. (ASM)

68-52 "New Grinding and Machining Processes Promise Conservation of Diamonds"—M. Bryan Baker; *Machine and Tool Blue Book*, v. 48, December 1952, pp. 219, 221-227. "Electro-erosive", electrosparking, electroarcing, ultrasonic and combined processes. (ASM)

69-52. "Which Method to Evaluate Surface Roughness"—Irwin Goldman; *Materials and Methods*, v. 36, December 1952, pp. 89-93. Numerous methods of measuring surface roughness. Advantages of binocular microscope. (ASM)

70-52. "Surface Profile Measurement Using the Microscope"—S. Tolansky; *Laboratory Practice*, v. 1, pp. 193-196. The technique described can be used with magnifications ranging from 100 to 2000 and resolutions to 0.25-micron are obtainable. The method is simple to apply, inexpensive and nondestructive. It has the advantage of giving profiles over an extended area. Typical results. (ASM)

71-52. *Manual on Cutting of Metals with Single-Point Tools*, Ed. 2, American Society of Mechanical Engineers, New York, 1952, 546 pages. Types, uses, and preparation of single-point tools; mechanical characteristics and structures of work material; definitions, functions, and classification of cutting fluids; cutting forces, gross and net power at the cutter; net unit power for machining metals using a single size cut; economics of metal cutting; and tabular data on cutting speeds and horsepower for various feeds and depth of cut when turning steel and cast iron. (ASM)

A cross-reference subject index of the foregoing abstracts will be presented in the June issue.

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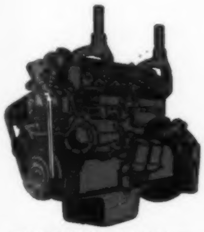
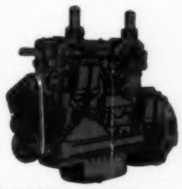


UD-1091 203 hp. @ 1400 rpm
Disp. 1090.6 cu. in., 6 cyls.



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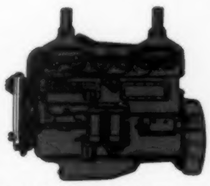
Disp. 691.1 cu. in., 6 cyls.



UD-525 121 hp. @ 1800 rpm
Disp. 524.9 cu. in., 6 cyls.

UD-14A 89 hp. @ 1600 rpm
Disp. 460.7 cu. in., 4 cyls.

UD-350 78 hp. @ 1800 rpm
Disp. 349.9 cu. in., 4 cyls.

UD-264 57 hp. @ 1800 rpm
Disp. 263.9 cu. in., 4 cyls.

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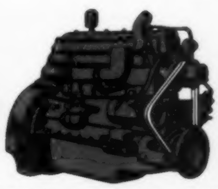
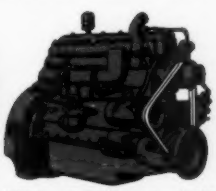
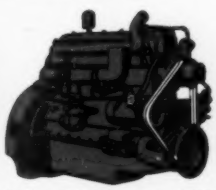


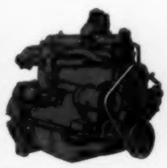
U-450 118 hp. @ 2200 rpm*
RD-450 182 hp. @ 3000 rpm+
Disp. 450.9 cu. in., 6 cyls.



U-406 104 hp. @ 2200 rpm*
RD-406 175 hp. @ 3200 rpm+
Disp. 405.9 cu. in., 6 cyls.



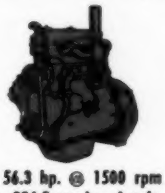
U-372 95 hp. @ 2200 rpm*
RD 372 165 hp. @ 3200 rpm+
Disp. 372 cu. in., 6 cyls.



U-282 79 hp. @ 2400 rpm
BD-282 137 hp. @ 3600 rpm+
Disp. 282.5 cu. in., 6 cyls.

U-240 66 hp. @ 2400 rpm
SD-240 131 hp. @ 3800 rpm
Disp. 240.3 cu. in., 6 cyls.

U-220 64 hp. @ 2400 rpm*
SD-220 104 hp. @ 3600 rpm+
Disp. 220.5 cu. in., 6 cyls.



U-9 56.3 hp. @ 1500 rpm
Disp. 334.5 cu. in., 4 cyls.

U-264 56 hp. @ 1800 rpm
Disp. 263.9 cu. in., 4 cyls.

U-164 38.5 hp. @ 1800 rpm
Disp. 164 cu. in., 4 cylinders

U-2A 25.8 hp. @ 1800 rpm
Disp. 113.1 cu. in., 4 cyls.

U-1 17 hp. @ 2500 rpm
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Stress Relief

RESUMING his unearthing of the origin of things familiar to engineers, Gene Murphy of Minneapolis-Honeywell sets out to show that

Necessity Is Not Always the Mother

Many many years ago, in the far northern part of that great land mass that is now known as the continent of Australia, there lived a cave dweller by the name of M'Gumbo. Now this M'Gumbo was an individual of great perspicacity and enterprise, and was the envy of his neighbors by virtue of the fact that his was a split-level cave, while theirs were all of the ranch, or sleep-wet-during-the-rainy-season, type.

Moreover, M'Gumbo possessed a certain amount of inventive genius, and had fashioned out of wood a circular contrivance that he called a Wahile in honor of an elderly aunt who was quite fat and for whom he had considerable affection. What purpose it might serve, he knew not, nor did his neighbors, but it fascinated them greatly, and they thronged to his cave daily to observe it and to turn it by hand, for M'Gumbo had mounted it upon

an axle of sorts so that it stood perpendicular to, and several inches above, the floor of the cave.

But, as has ever been the case where humans were involved, there were in the community those who were envious of M'Gumbo and who wished to do him harm. One of these, by name M'Boola, con-

ceived a most diabolical plan.

Having, among his possessions, a rather moss-covered, yet at the same time voracious, crocodile, it occurred to M'boola that were he to loose this creature in M'Gumbo's cave, the results that he desired might well be achieved.

This he did on the following night, but, alas, he had failed to reckon with M'Gumbo's split-level cave, and the crocodile, unable to mount to the upper level where slept M'Gumbo, made shift to eat

what was at hand, which in this case happened to be the famous Wahile.

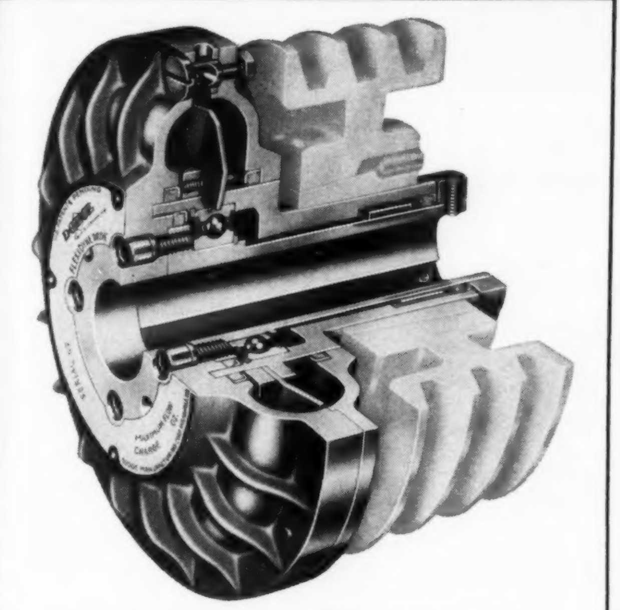
He did not eat the entire Wahile, but rather nibbled his way daintily around its outer circumference. Since his two front teeth were missing, the result was most odd, and instead of presenting a smooth circular rim, the circumference of the Wahile now consisted of a series of alternating peaks and valleys.

M'Gumbo, however, as is so often true of inventors, having perfected his Wahile, rapidly lost interest in it and, in fact, did not even notice that which the crocodile had done, although he could not help but notice the crocodile since he tripped over it on the following morning and upset a bowl of fire ants that he had been most carefully preserving for use in a future scientific experiment.

Being a strong believer in capital punishment, and also being slightly hungry at the time, he straightway slew the offending crocodile and proceeded to barbecue it for breakfast.

Now, the invention with which M'Gumbo was currently concerned was a long wooden shaft to one end of which he had attached a crank. By turning the crank he

(*Continued on Page* 362)



FLEXIDYNE DRIVE (with Taper-Lock Sheave in phantom).

4. Rotor and housing reach identical speeds—the Flexidyne operates with ZERO SLIPPAGE between motor and load at normal running speeds.

5. Before overloads cause damage, the Flexidyne rotor slips relative to the housing, overcoming the friction and wedging action of the flow charge. A thermal switch (optional) automatically cuts the electrical circuit if an overload persists.

6. The amount of the flow charge determines the torque capacity.

WHAT IT DOES

The Flexidyne gives you the *exact* starting torque you need, for anything from the smoothest to the fastest start. Once the load reaches normal speed, there is zero slip, giving 100% efficiency. Also, it provides *accurate* overload protection, as it can be set to slip at any desired load. During starting and overload periods the current draw is at a minimum because with the standard Flexidyne setting the motor is never pulled down to less than 90% of synchronous speed.

All this is due to Flexidyne's completely new principle, which produces *constant torque* for a given input speed, regardless of the percentage of slip between the rotor and housing (which occurs only during starting or overload).

The Flexidyne is simple to select *off the shelf.* Each size has a standard horsepower rating and yet it is only a matter of minutes to vary the flow charge to give you your own *tailor-made torque* to suit the job.

With Flexidyne you get *uniform* performance regardless of changes in the surrounding temperature.

The Flexidyne has very long life and practically negligible maintenance. *Its simplicity guarantees its dependability.* Gas and diesel engines also benefit from all Flexidyne advantages.

Aside from Flexidyne's low first cost, low maintenance, and top efficiency, it permits the use of smaller, cheaper motors and controls with greatly reduced current demands and improved power factor. Its *smoother* starts and *gentler* overload protection avoid breakage and reduce maintenance on drives, gears, bearings and driven machinery.

FLEXIDYNE COUPLINGS

Two lines will be available—*Flexidyne Drives,* for convenient mounting directly on motor shafts and adapted for Dodge Taper-Lock Sheaves, and *Flexidyne Couplings* with Taper-Lock Bushings, for straight line drives. Several thousands of these units of French design, in capacities ranging from fractional to thousands of horsepower, are now in use in Europe. Dodge will first offer — from stock — four sizes rated at 3 to 30 hp at 1800 rpm. Other sizes will follow.

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DODGE
of Mishawaka, Ind.

Stress Relief

(*Continued from Page* 359)

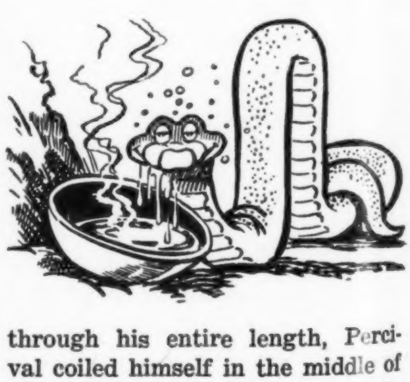
was able to turn the shaft, a phenomenon that pleased him mightily, and one which, he could not help but believe, might conceivably be of use to someone at some time or other if a few minor improvements could be made.

M'Gumbo, in addition to being an inventor of note, was also a great lover of wild life, and numbered among his friends a great rock python called Percival. Although Percival and M'Gumbo were close friends, the reptile suffered from a weakness that, at times, sorely tried the patience of the man. In brief, Percival was a hopeless alcoholic, and, since there are few things more disturbing than an intoxicated rock python, M'Gumbo was continually seeking new hiding places for his bowls of alcohol which he made from the fermented juices of certain fruits, and used in many of his scientific experiments.

For several weeks now, he had been successful in concealing from Percival his store of alcohol, but that unfortunate reptile, having by this time been reduced to a 20-foot length of tortured nerves, only redoubled his efforts to locate the nerve-soothing liquid.

At last there came a night when, M'Gumbo having retired, Percival twitched nervously into the cave, and discovered that which he sought, cleverly concealed in a bowl in which M'Gumbo was wont to store a supply of echidna spines.

Having drained the bowl, and, feeling a sense of wellness seep



through his entire length, Percival coiled himself in the middle of the cave and searched his brain for some act which he could perform that would bedevil the poor M'Gumbo, for in such manner worked the great reptile's mind

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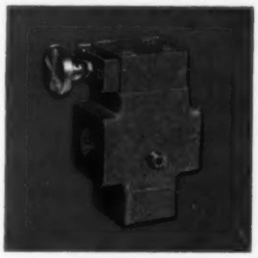

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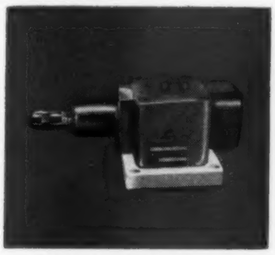

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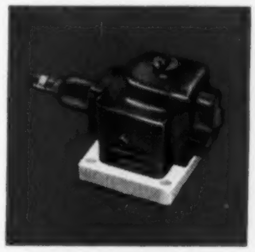
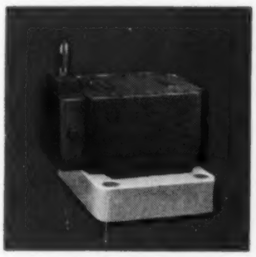


BY-PASS and CHECK VALVES (for counterbalance and sequence applications)



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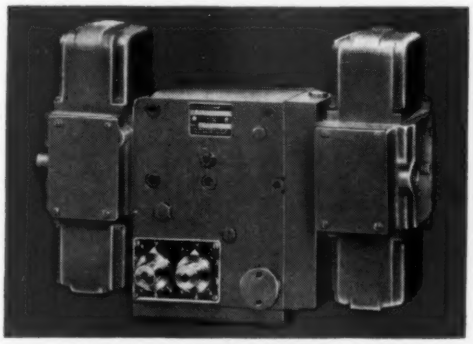
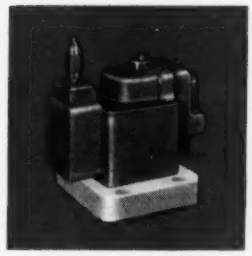


TRAVERSE and FEED CONTROL PANELS



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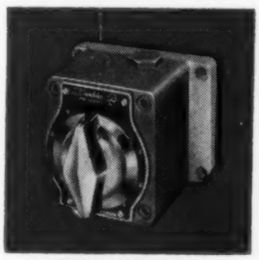
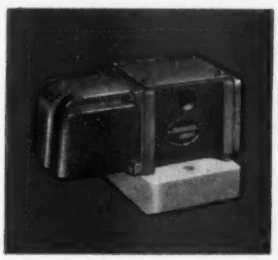


FLOW CONTROL VALVES



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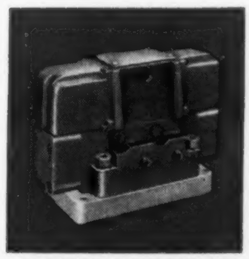

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when in the throes of an alcoholic seizure.

Gazing drunkenly about the cave, he beheld the crank and shaft, M'Gumbo's latest invention, and, knowing what great pleasure it gave the man to turn the crank and watch the shaft revolve, his reptilian cunning told him that he could best achieve his purpose were he to deprive his friend of this simple pleasure.

With this thought in mind, the huge python commenced to climb one of the two upright posts that supported the shaft in its position just above the Wahile. This climb, while, in truth, of no great distance, took the greater portion of the night to complete, for, because of the alcoholic haze that surrounded him, Percival was sorely afflicted with a regrettable lack of co-ordination between his head and his tail. Not less than a score of times during the night did his head, which had unknowingly reversed directions and started down the post, encounter his tail which was still on the way up. Thinking that some other python was attempting to interfere with his ambitious project, Percival, on each of these encounters caused his head to be involved in a fierce struggle with his tail, a misunderstanding that not only greatly slowed his climb, but also caused certain damage to his tail.

Percival, however, although inebriated, was nothing if not persistent, and so in due time he reached the horizontal shaft, and, winding along and around it, soon covered its entire length, whereupon, sore exhausted and more than a trifle giddy, he proceeded to fall into a deep alcoholic slumber.

M'Gumbo, awakening early, came down from his sleeping level and went at once to his crank and shaft, thinking to start the day out right by giving it a turn or two.

Seeing Percival twined along and around the shaft, M'Gumbo was angered and called out to him. "Come down, at once, thou drunken worm!" That his alcohol had been found, he knew, for the fumes in the room were of an intensity

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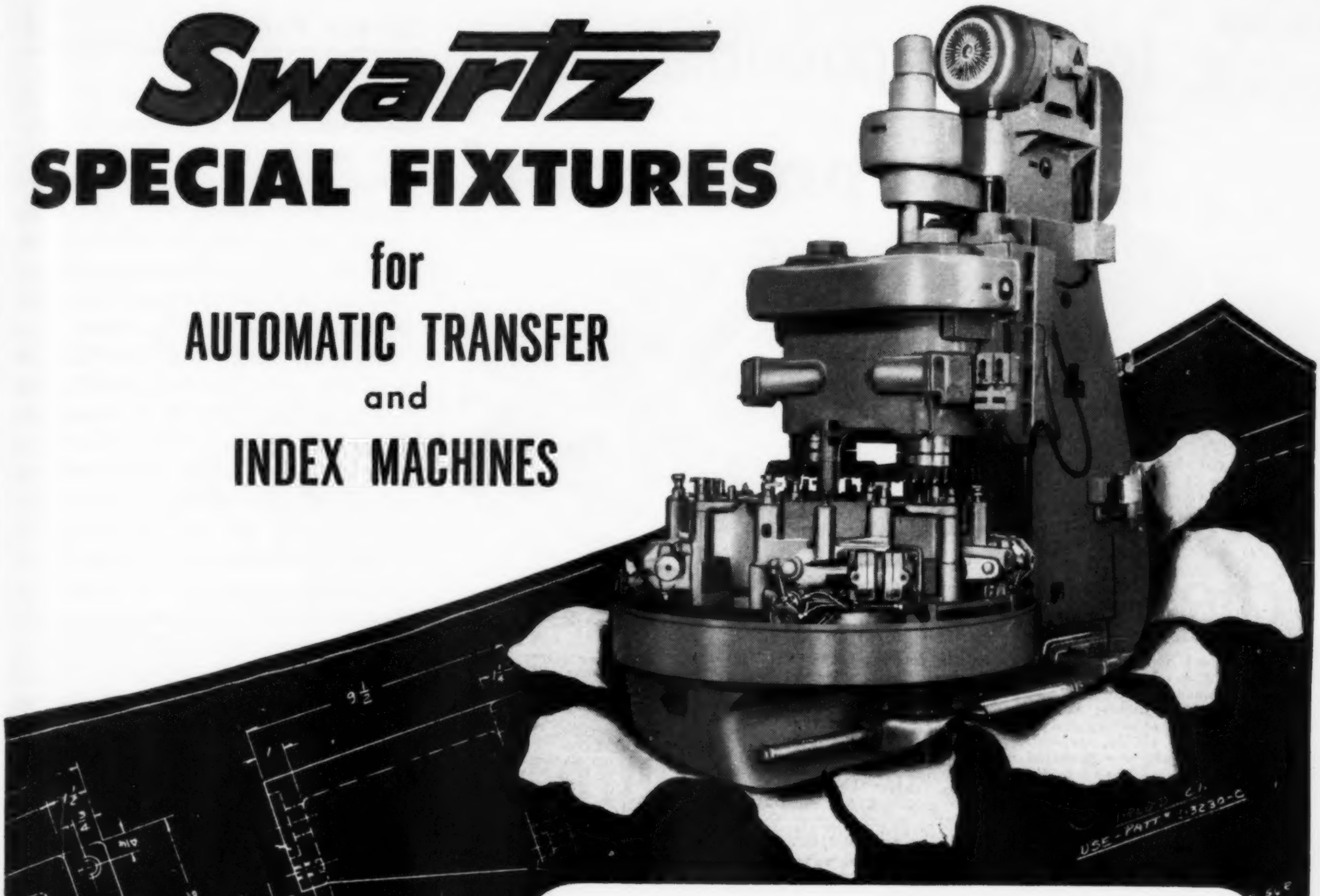

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To both buyer and builder of automatic machine tools, Swartz offers a specialized fixture-building service . . . complete in every detail, from part print to finished product. Swartz fixtures represent the accumulated experience and skill of more than 30 years in this highly specialized field, and the advantages of Swartz service have become increasingly important with the rapid growth of automation.

If you use or build automatic machines, you can profit from Swartz service. Assure yourself of continuous production, with a minimum of costly down-time! *You can,* with dependable Swartz fixtures! They are guaranteed. Call in a Swartz engineer, to discuss your fixture requirements. You'll be glad you did.

Swartz service is presented in a new brochure, "Advancing Automation", and a copy will be mailed on request.

SWARTZ TOOL PRODUCTS
Division of Jefferson Corporation
13338 FOLEY AVENUE • DETROIT 27, MICHIGAN

Designers and Builders of: Special Fixtures for Automatic Machine Tools, Pump Jigs, Standard Fixtures, Fixture Locks

Swartz fixtures were specified for the 4-station Rotary Index Machine shown in the above illustration. The result—dependable, on-the-job fixture performance!

Here is a typical Swartz fixture installation, on a multi-station Transfer Machine. Another example of how Swartz efficiently serves the builders of modern automatic machine tools.

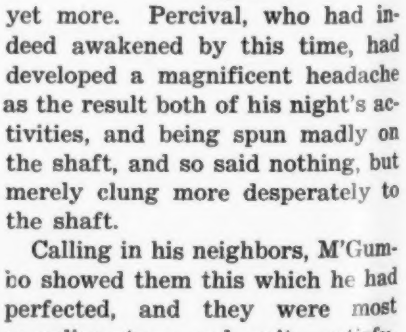
More than 30 Years of Specialized Service to the Machine Tool Industry!

to make one's eyes water, and left no doubt as to the reptile's pitiable condition.

But Percival, what with the wining and winding he had been doing all through the night, heard him not, and continued to slumber and in fact snored gently a time or two.

By this time, M'Gumbo was in a towering rage, and, seeing that a coil of Percival's body was fitted into one of the valleys between two peaks on the circumference of his Wahile, thought that mayhap a turn or two of the crank might cause his intoxicated friend to become discomfited to the extent that he might awaken and descend from the shaft.

So thinking, he gave the crank a turn. However, greatly to his amazement, Percival did not awaken, but the Wahile turned a bit. Ablaze with excitement at this new discovery, he churned furiously at the crank, and the Wahile moved



yet more. Percival, who had indeed awakened by this time, had developed a magnificent headache as the result both of his night's activities, and being spun madly on the shaft, and so said nothing, but merely clung more desperately to the shaft.

Calling in his neighbors, M'Gumbo showed them this which he had perfected, and they were most complimentary and quite satisfyingly envious.

"And what", asked an elder of the community, "shall be the name of this gloriously impressive and absolutely worthless contrivance?"

"Well, now", answered M'Gumbo, "since that great lout of a Percival, through no fault of his own, aided me in this discovery, I think that it would be most generous of me to call this invention

Stress Relief

a *worm and Wahile.* As for its worthlessness, that remains to be seen, for it is my intention to charge people a certain fee to witness the operation of my contrivance in the future".

And in the years that followed, M'Gumbo made good his promise and became a wealthy man even after allowing for the expense of keeping Percival in a condition of intoxication, for the reptile would not—nay, claimed he could not—play his part in the act while sober.

And among those who paid a fee to see the contrivance were scholars from a foreign land, and they returned to their homes and made similar contrivances, but did not use snakes in so doing, and a contrivance of this type came to be known as a *worm and wheel.*

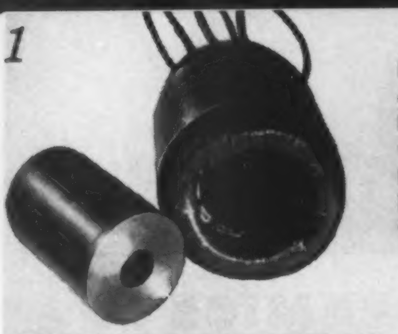
They Say . . .

We can make some observations on the characteristics of individuals who make up the more successful stratum of the profession. In this case one is fortunate to be able to turn to the words of Henri Le Chatelier, one of the prominent scientists and engineers of France. M. Le Chatelier analyzed and compiled the outstanding personal characteristics of successful scientists and engineers and came up with the conclusion that four qualities were always present and hence must be basic characteristics of a successful engineer: activity (or drive), imagination, judgment, and knowledge.

Another author listed 18 qualities observed in successful executives. The first two were "They work hard," second, "They have imagination" which obviously are in exact correspondence with Le Chatelier's first two prime qualities.

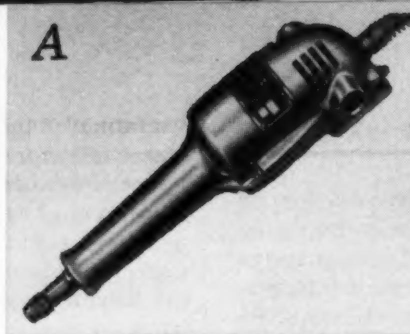
I would suggest that there is a fifth quality beyond the four given by Le Chatelier; one which is highly necessary for the bulk of engineers, namely—adeptness in human relations (that much maligned, much misused term).—C. C. FURNAS, *director, Cornell Aeronautical Lab. Inc.*

1



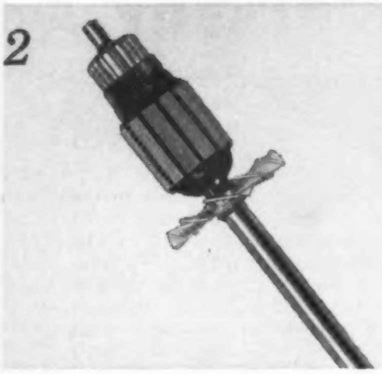
R & M Polyphase motor parts, consisting of rotor and stator, horizontal position. Light weight and reserve power for heavy duty use were the most important motor characteristics required.

A



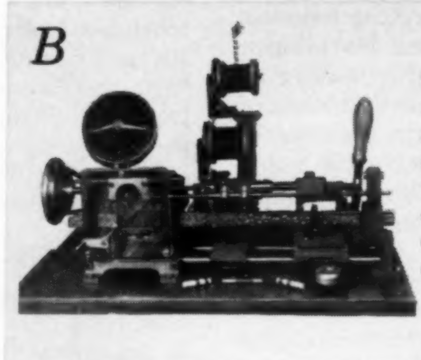
The ultra-high-speed Sk Grinder, made by Skil C poration, packs twice t power per pound of oth grinders of similar weight. T and die makers say it's gre

2



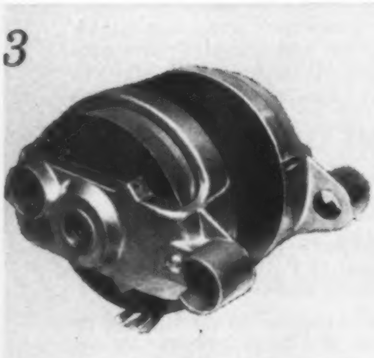
This motor had to be lightweight, powerful and capable of running for long periods at 36,000 R.P.M. It's dynamically balanced with a diamond-turned commutator and specially anchored windings.

B



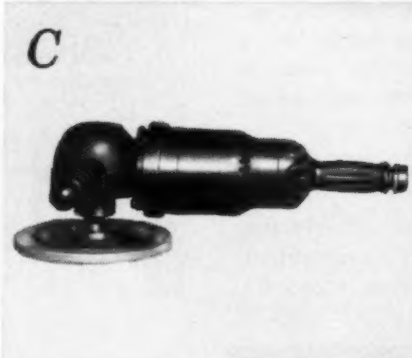
The Geo. Stevens Model 1 Progressive Universal Wind made by Geo. Stevens M Co., Inc., world's largest ma facturer of coil-winding m chines. One of a complete li of R & M Motor-equipp machines.

3



This powerful R & M Motor has a high starting torque for quick response; it runs cooler than normal, it's exceptionally quiet, and it's *compact*. Extra-heavily insulated, dynamically balanced, 100% inspected.

C



The powerful, easy-to-hand Buckeye Hi-Frequency Sand It's ideal for automotive o industrial applications whe tools are subjected to co tinuous, heavy duty servic R & M furnishes motors t Buckeye Tools Corporation capacities from 3/16 to 4 H

4

Variable speed was a must for this R & M Motor—to permit a wide selection of speeds without need for changing belts or pulleys. Motor is ¼ HP, AC-DC 5000 R.P.M., ball bearing equipped and open ventilated.

D

The IBM Executive made b International Business Machin Corp., the only typewrit manufacturer exclusively pr ducing electric machines. I the mark of a modern offic

Can YOU match these motors to these tools and machines?

Here are some R & M fractional horsepower motors, and the machines for which they were selected or designed. Can you guess which goes with which? The answers are printed at the right . . . what was *your* score?

THE ANSWERS

R & M motors and motor parts, and the machines on which they are specified as standard, match up as follows:

1-C 2-A 3-D 4-B

ON COMPLETE MOTORS OR MOTOR PARTS . . .

Don't "guess" . . . let Robbins & Myers do a *scientific* job of matching the all-important motor to your product! Regardless of whether you need a motor that's standard or custom-designed . . . motors with special housing designs or motor parts to fit your housings, remember that R & M Motors are powering all types of equipment, such as . . . .

Portable Saws
Drills
Nut Setters
Hammers
Routers
Screw Drivers
Hedge Trimmers
Lawn Mowers
Nibblers
Lock Mortisers
Valve Grinders

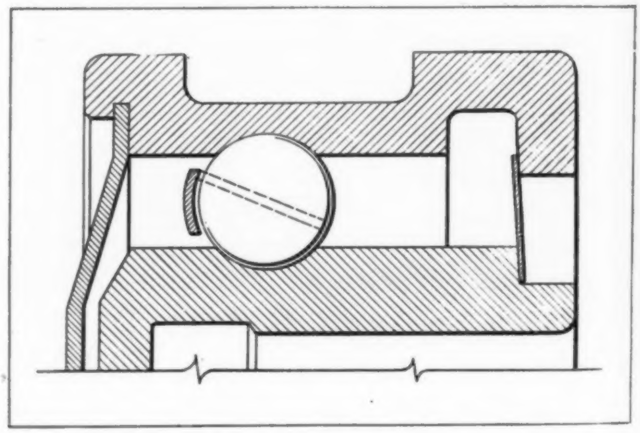
Vacuum Cleaners
Files
Sanders
Pumps
Compressors
Hones
Business Machines
Cast Cutters
Food Mixers
Polishers
Planers

Portable Grinders
Sirens
Hair Driers
Advertising Devices
Ventilating Equipment
Oil Burners
Surgical Instruments
Grease Guns
Vibrators
Die Sinkers
Waxers

NOTEWORTHY Patents

All Metal Bearing Seal

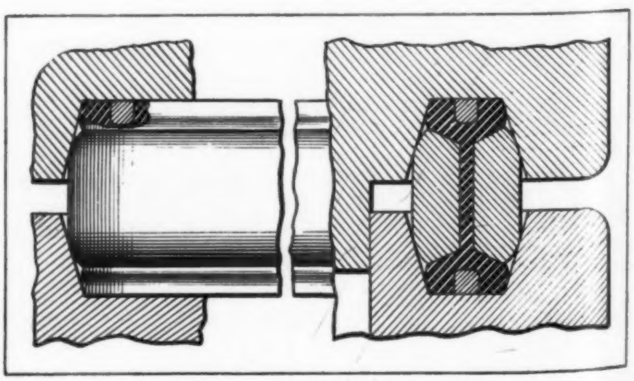
A thin spring-metal ring is utilized as a ball-bearing lubricant seal by mounting it so that it forces itself into sealing engagement with the bearing races. An inner shoulder is machined into the outer race to accommodate the outer edge of the sealing ring. The inner edge of the ring rests against an outer shoulder of the inner race. When the bearing is assembled,

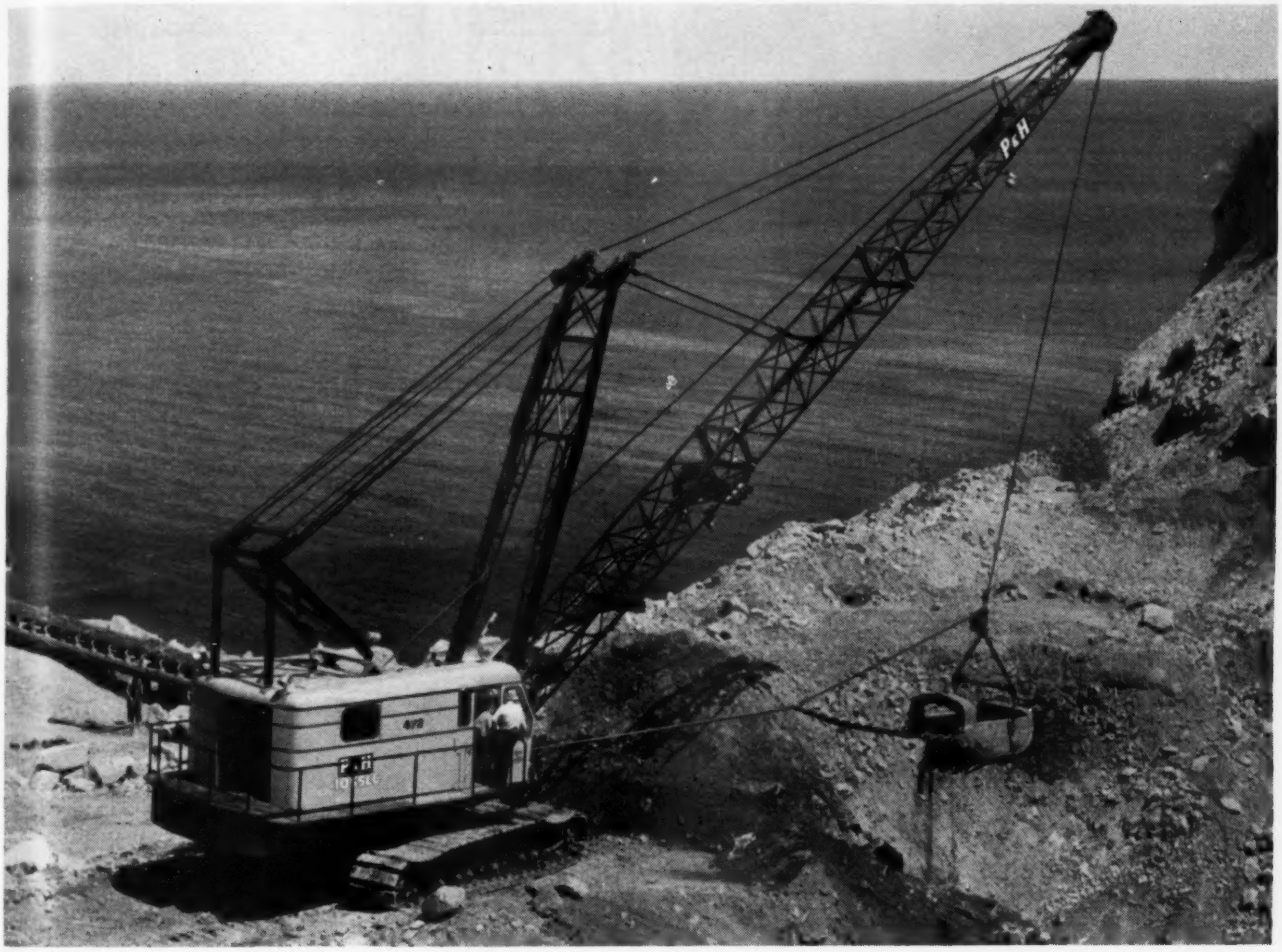


the shoulders are slightly offset so the ring is stressed laterally. In this way the edges of the ring form an effective seal with the shoulders of the races. Although simple in construction, this ring seal will effectively enclose thick lubricants at high operating temperatures without deterioration. *Patent* 2,689,772 *assinged to Saywell Associates by A. B. Jones Jr.*

Fluid Tight Sealing Ring

Having the advantage of providing a metal-to-metal contact between the parts connected, this seal also has a resilient core to maintain sealing contact. Formed as a ring with an I-shaped cross section, the



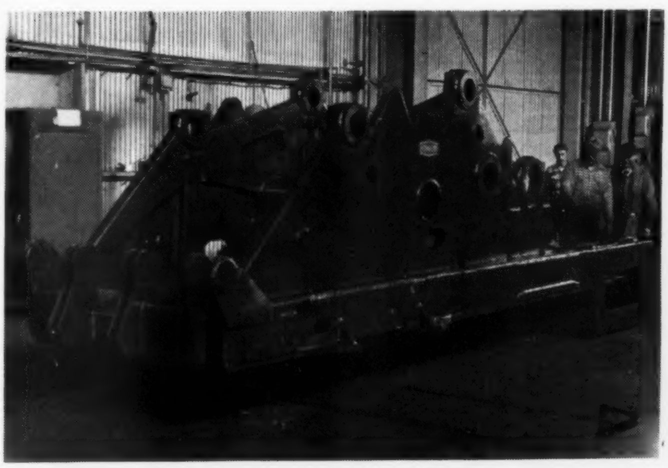


GRAVER Fabricates All-Welded Revolving Frames for P&H Power Shovels

The versatile P&H Dragline pictured above, feeding rock onto a conveyor (Model 1055 LC) uses an all-welded revolving frame for extra strength. Graver recently fabricated five such assemblies for the Harnischfeger Corporation, one of which is shown in the inset.

This is an integrally welded rigid unit of box section design to withstand the great variety of stresses it will encounter. Traditional Graver quality is seen in the uniform welds which were inspected during manufacture by the most modern and comprehensive techniques. These include the initial accurate dimensional inspection on specially designed layout tables, periodic visual inspections, and magnetic particle and X-ray inspections.

Graver has achieved a reputation for developing new equipment and advanced techniques and is expert in welding carbon and stainless steels, and aluminum. For the more complex, difficult welding problems consult your Graver engineering representative. Meanwhile write for new illustrated brochure, "WELDMENTS."



GRAVER TANK & MFG. CO., INC.

East Chicago, Indiana

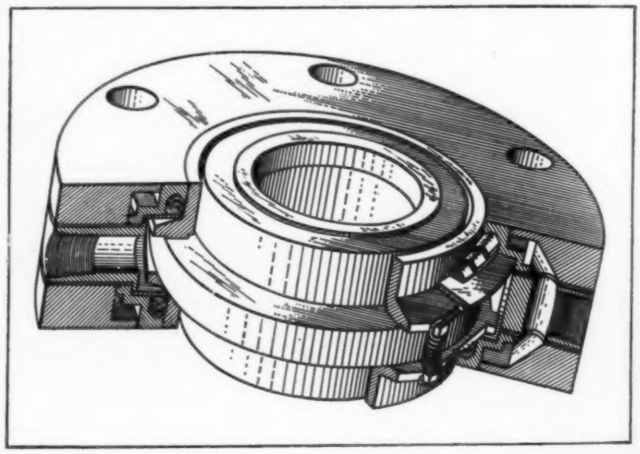
CHICAGO • NEW YORK • PHILADELPHIA • EDGE MOOR, DEL. • CATASAUQUA, PA. • PITTSBURGH • CLEVELAND • DETROIT • TULSA • SAND SPRINGS, OKLA. • HOUSTON • ODESSA, TEXAS • CASPER, WYO. • LOS ANGELES FONTANA, CAL. • SAN FRANCISCO

GRAVER *... source for quality weldments*

resilient core fits between two metal rings. Tapered recesses into which the seal assembly is fitted force the rings together, compressing the resilient core. Two additional metal rings fitted into the core prevent excessive deformation. Combining high wear-resistant qualities with positive sealing, the ring may be used between the body and bonnet of a plug valve. *Patent* 2,687,909 *issued to G. R. Blackman and T. L. Putnam.*

Fluid Seal

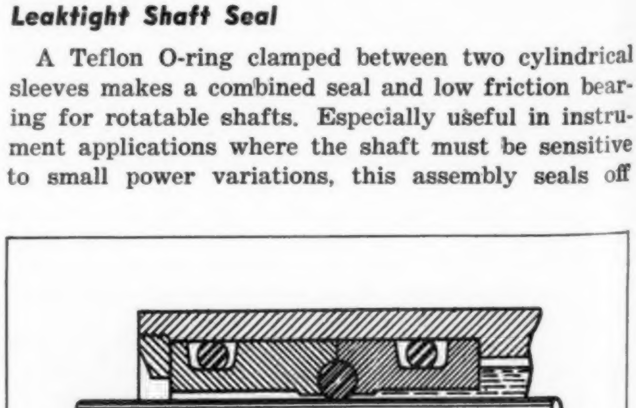
Fluid is utilized as a means of sealing a rotating shaft under conditions of varying pressure. Oil or a similar sealant is enclosed in a cavity formed around the rotor by nonrotating metal sealing rings. Springs maintain the sealing rings in engagement under conditions of pressure equilibrium between the sealing



cavity and the liquid in the vessel. Pressure changes outside the seal are automatically equalized by corresponding pressure changes within the seal cavity. Time to reach this equilibrium may be controlled by the volume of sealant in the cavity. *Patent* 2,686,068 *assigned to Viscoseal Corp. by D. R. Lewis.*

Leaktight Shaft Seal

A Teflon O-ring clamped between two cylindrical sleeves makes a combined seal and low friction bearing for rotatable shafts. Especially useful in instrument applications where the shaft must be sensitive to small power variations, this assembly seals off

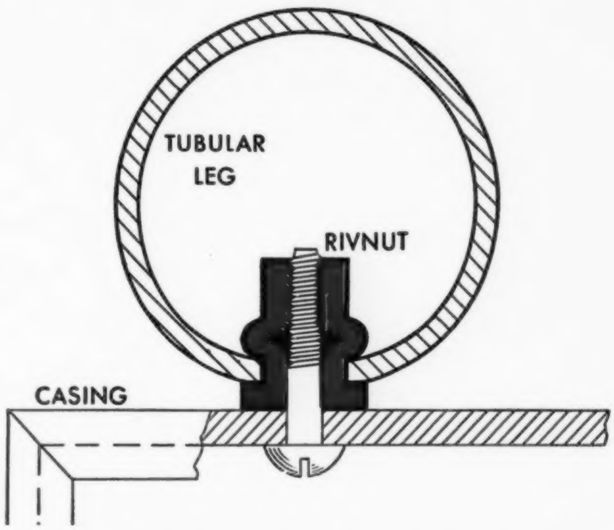


B. F. Goodrich RIVNUTS cut costs by reducing assembly time

B. F. GOODRICH RIVNUTS boost hourly output because they provide a firm, accurate nut plate in one, quick operation. Nuts and bolts, welding, clinching, tapping are eliminated.

The diagram at right shows why the Big Boy Mfg. Company switched from nuts and bolts to Rivnuts for fastening tubular legs onto its barbecue. One person installs a Rivnut in a couple of seconds. Threads are clean for screw attachment. There are no boltheads on the outside to detract from the barbecue's clean lines. Assembly is faster. Manhours are saved, too, in knockdown for shipping.

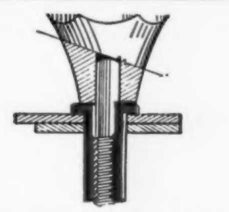
If you're looking for a fastener that can improve your product and cut production time, get more information and engineering help by calling in a B. F. Goodrich Rivnut engineer. The B. F. Goodrich Company, Department MD-55, Akron, Ohio.



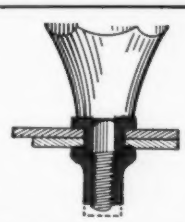
B. F. Goodrich Rivnuts cut costs in other applications on this Big Boy Barbecue. After legs are fastened, worker installs Rivnut that does 3 jobs —serving as bearing, locating and locking device on movable fire bed.

Rivnuts provide at least 6 clean threads in one simple operation!

1 Rivnut is threaded onto pull-up stud of a manual or pneumatic heading tool.



2 Rivnut is inserted—head firmly against work—tool at right angles to work.

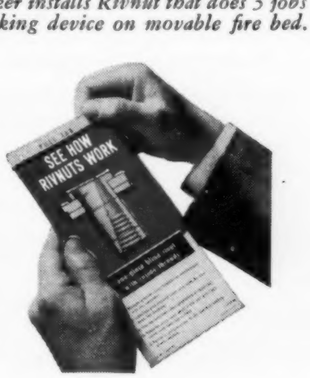


3 Tool lever operates pull-up stud, forming a bulge in the Rivnut shank.

4 After upset, Rivnut threads are still clean and intact, ready for screw attachment.

SEND NOW FOR FREE RIVNUT DEMONSTRATOR

Demonstrates with motion how you can use Rivnuts to fasten TO and fasten WITH. Explains construction, simplicity of installation. Get your free copy today by writing to: The B. F. Goodrich Company, Department MD-55, Akron, Ohio.



B.F. Goodrich

RIVNUTS

The only one-piece blind rivet with threads

Noteworthy Patents

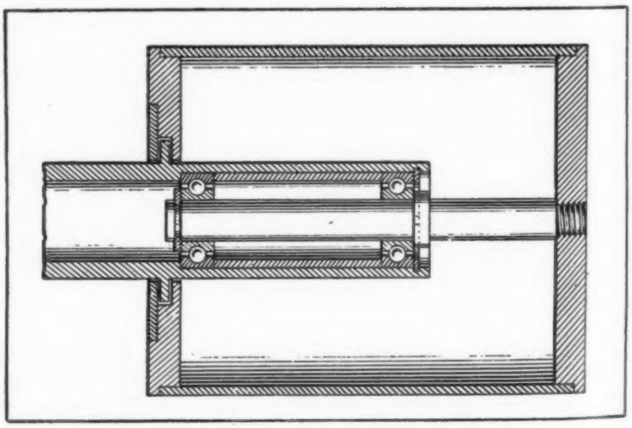
a high-pressure area from which the rotatable shaft must transmit recording indications. Two cylindrical sleeves surrounding the shaft are fastened inside a tubular housing. Together they form a recess into which the plastic O-ring is secured. Stationary rubber O-rings are fitted between the sleeves and tubular housing to complete the seal. *Patent* 2,690,360 *assigned to Foxboro Co. by C. D. Young.*

Rotating Pinion Pins

Wear and friction reduction in a planetary gear set is accomplished by rotating the pinion pins to reduce the relative speed between the planet pinions and their supporting pins. Auxiliary planet pinions fixed to the pins engage a second ring gear. The auxiliary pinion is of larger diameter than the driving pinions; thus supporting pins rotate, but at a slower speed than the pinions. With proper auxiliary gear dimensions a mean rotational speed between zero and the pinion speed can be obtained to act as an intermediate step between the high-speed pinions and their supporting pins. *Patent* 2,688,263 *assigned to United Aircraft Corp. by A. M. Rockwell.*

Instrument Bearing

Cantilever mounting of this precision instrument bearing affords protection against damage from impact while retaining high sensitivity. Two bearings inside a counterbore in the rotating shaft, are mounted on a cantilevered support fastened to one end



of the housing. Flexibility of the cantilever support permits minor angular misalignment without damage to the bearings. In case of severe misalignment, a flange provided around the shaft strikes the housing, limiting movement to a safe value. Because of its labyrinth construction, the assembly also provides protection to the bearings from dust or other foreign material. *Patent* 2,686,698 *assigned to Servomechanisms Inc. by D. W. Moore Jr.*

Copies of the patents briefed in this department may be obtained for 25 cents each from The Commissioner of Patents, Washington 25, D. C.

ANNOUNCING THE NEW MAXITORQ "DISC-PAC"

A "DO-IT-YOURSELF" UNIT
FOR BUILDING YOUR OWN CLUTCH

Due to a growing demand for Maxitorq Floating Discs, we now introduce The *MAXITORQ DISC-PAC* . . . a self-contained unit independent of the actuator.

Patented Maxitorq Separator Springs that prevent drag, abrasion, and consequent heating in neutral . . . and the Maxitorq Locking Plate which locks all discs onto body . . . give you the outstanding features that are so highly favored by machine and product designers.

Thus you may build your own clutch or brake from our standard stock Maxitorq parts. The Disc-Pac keys to your shaft and is easily replaced. Units are available in 8-disc diameters from 2" to 8"; 1/4 to 15 h.p. at 100 r.p.m. . . . with 3 lugs on the smallest size, 8 lugs on the 3 h.p., and 12 lugs on the 5, 10 and 15 h.p. capacities.

The Disc-Pac fits Maxitorq standard Driving Rings in the event that you want to use them. As with the Maxitorq Clutch, all assembly, take-apart and adjustments are manual . . . no tools required.

Write Dept. MD-5 for full specifications and quotations.

1CJ54

THE CARLYLE JOHNSON MACHINE COMPANY
MANCHESTER • CONNECTICUT

New Machines

Materials Handling

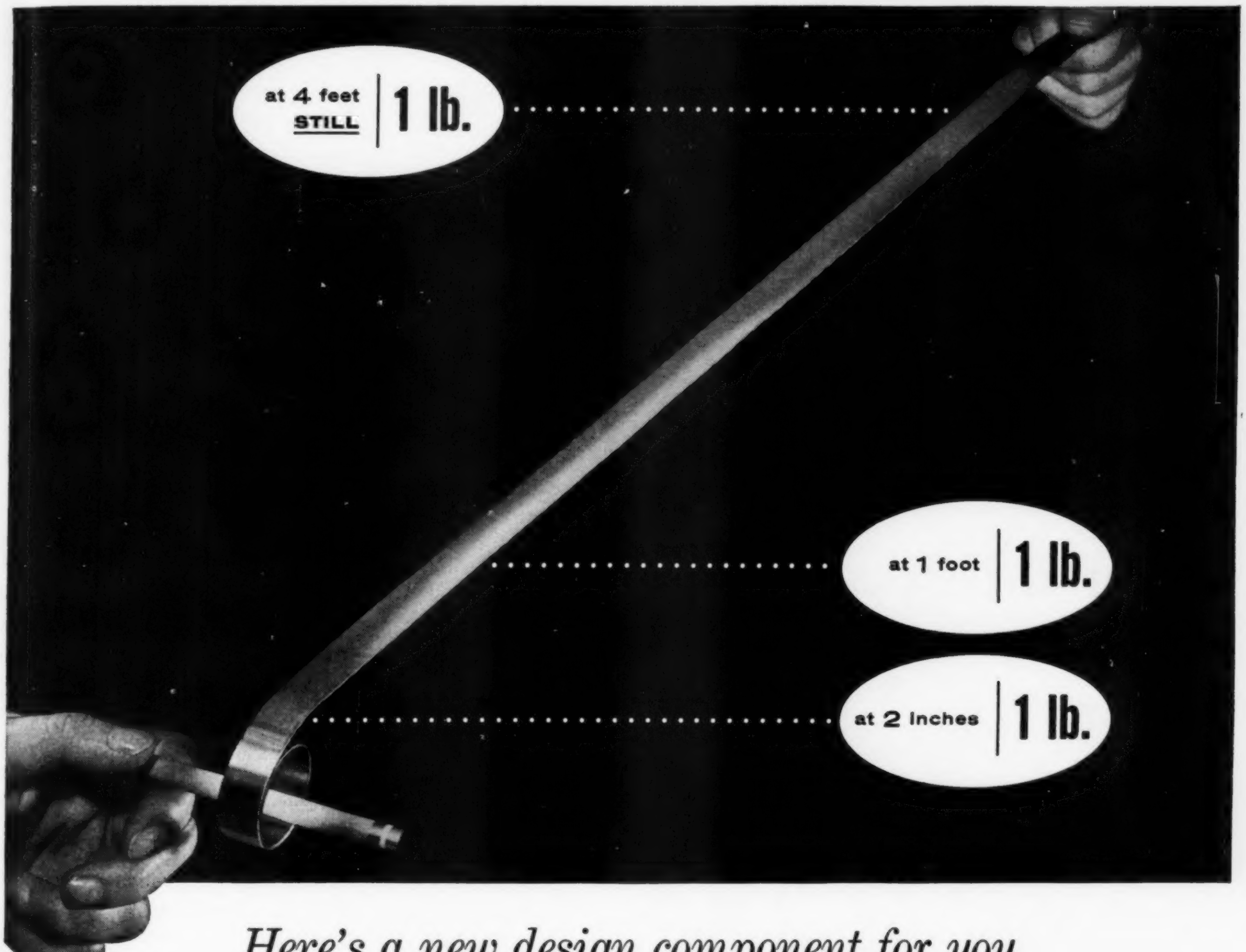
Conveyor Transfer Machine: Floor-mounted unit removes parts from the hooks of an overhead monorail conveyor and transfers them to a roller conveyor at the rate of 300 pieces per hour. Machine can also be arranged to select certain parts and reject all others from a conveyor which is carrying different parts. In addition, it can be used to pick up and transfer parts from a roller conveyor to overhead monorail hooks or to pick up parts from either a roller or a monorail conveyor and place them in a machine. Machine is particularly adaptable to round part shapes but can be modified to handle other shapes, as well as baskets and boxes. *General Tool Co., Reading, O.*

Coil Handler: Combination coil lift and decoiling reel handles coils weighing up to 40,000 lb. Elevation of lift is by mechanical or hydraulic means; traverse action is by either electric or hydraulic drive. Lift can be pit or floor-mounted. Decoiling reel is furnished free-running or motorized for constant speed drive or for threading only. It is equipped with drag type brake to prevent overrunning. A double cone type reel is also available. Hydraulically expansible mandrel is mounted on Timken tapered antifriction bearings; expansion can be accomplished by means of motor or manually. Expansion range is made to suite coil requirement. *Dahlstrom Machine Works Inc., Chicago, Ill.*

Parts Feeder: Assorted sizes and shapes of electronic parts are handled by vibratory parts feeder, which aligns, washes and dries each individual part. Bowl of the feeder is filled with deionized water. Parts are fed down around the outside track of the bowl into the water, are washed by constant pulsating movements of the water, and are then moved up and around the vibrating spiral feeder. Excess water drains through holes in the spiral. Parts are handled without damage. *Syntron Co., Homer City, Pa.*

Metalworking

Horizontal Surface Grinder: Saddle and table of the new Blohm horizontal surface grinder are carried on ball bearing assemblies operating on hardened, precision ground chromium-nickel steel ways. A 5-hp motor is mounted directly on the spindle, which runs on adjustable tapered bronze bushings with pressure lubrication. Wheels up to 4 in. wide can be used in conjunction with a cross feed varying to 2½ in. per stroke. Table and spindle design, combined with sturdy overall construction, minimize vibration and provide maximum concentricity. Microtip in-feed and depth-feed control permits accurate adjustment. Optional Finimatic device provides for automatic



Here's a new design component for you

THE FIRST CONSTANT FORCE SPRING!

Do *you*, too, want to simplify a product design problem—reduce weight, miniaturize, cut cost, *improve* the product, or even create a *new* product?

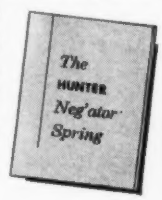
Can you use a *constant force spring* that's *not only a spring* but also a *motor*, a *counterbalance*, a *clamp*, *clip*, *slot closure*, and anything else *you* might make it?

The Hunter Neg'ator *constant force* spring upsets all previous spring principles. In addition to a zero gradient, negative or slightly positive gradients are also possible with the Neg'ator.

Hundreds of ingenious engineers have already used the Neg'ator spring to obtain—

- Tremendous extensions—over 30 times the original size—with no appreciable force build-up.
- Driving torques with longer duration and *no* heavy wind-up.
- Full force available from the very beginning of the stroke right up to the completion of the return stroke.
- The equivalent of a dead weight (in a range sufficient to counter-balance a mouse or a man) in one handful.
- Many other unusual characteristics.

Are *you* ready to learn more about this remarkable new spring element? We're ready to tell you. Just ask for our new bulletin, "The Hunter Neg'ator Spring". This bulletin describes the Neg'ator force characteristics, and its variety of forms and applications. Also included are many "thought provokers" for applying this promising new mechanical element.



THE HUNTER
neg'ator
constant force spring

HUNTER SPRING COMPANY
Lansdale (Phila.), Pennsylvania
SPRINGS • STAMPINGS • TEST APPARATUS

grinding. *Maserati Corp. of America, Westbury, N. Y.*

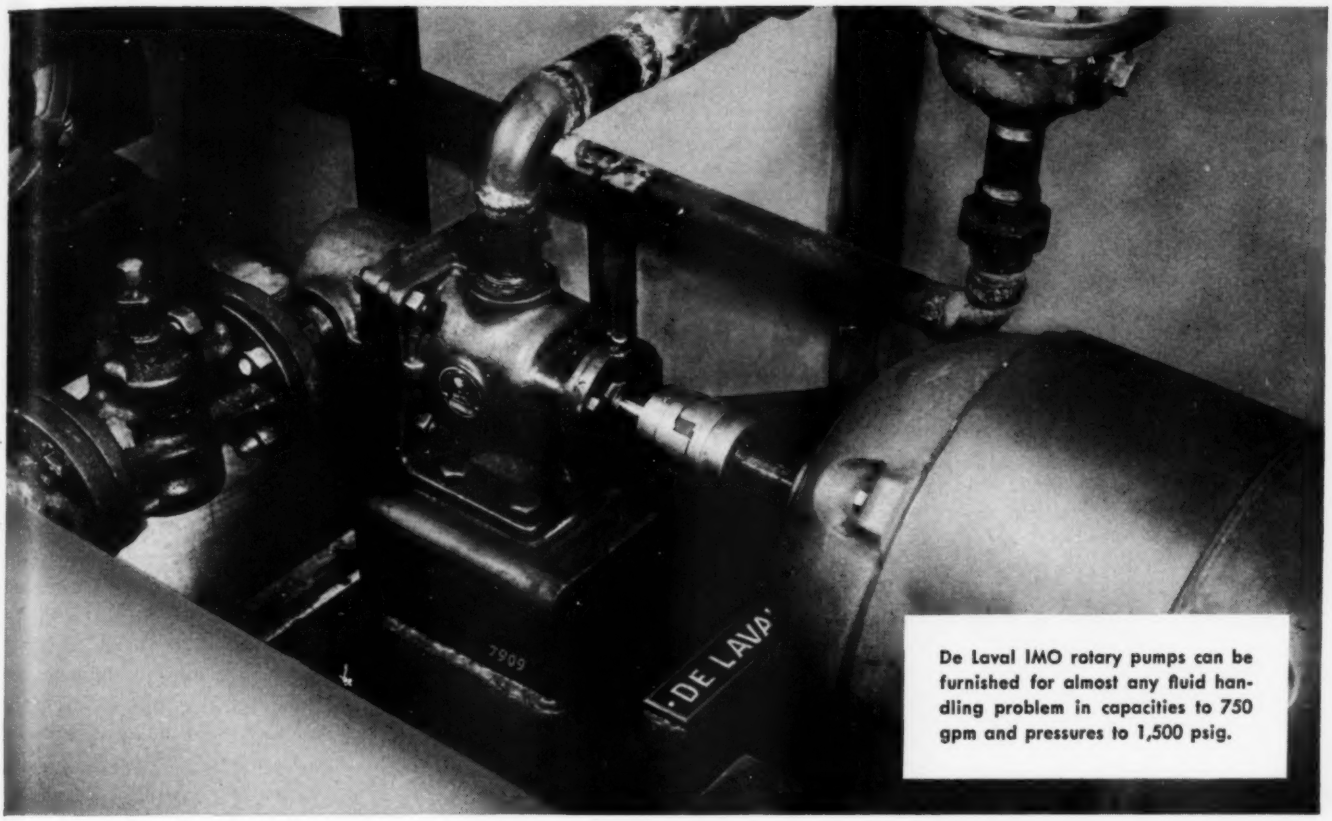
Welder: General purpose ac welder covers a current range of 25 to 295 amp. It provides a 50 per cent duty cycle in the normal welding range of 200 amp, with somewhat lower duty cycles when higher settings are used. A low-range open-circuit voltage of 75 v provides easy starting and facilitates use of low hydrogen and stainless steel electrodes. Type WK29A welder includes a 230-v primary circuit; for heavier applications, type WK29L includes a 230-460-v reconnectable primary circuit. *General Electric Co., Schenectady, N. Y.*

Lathe: No. 6560 lathe has adjustable-speed drive with a range of 38 to 1200 rpm. Other specifications are: 14⅝-in. swing over bed, 9-in. swing over saddle, 1⅜-in. spindle hole, 1-in. collet capacity, and 40 in. between center. Hardened and ground steel spindle turns on two double rows of oversize ball bearings. Lathe bed is 68 in. long and 10 in. wide. The two V-ways and two flat ways are precision ground. *Lathe Div., Logan Engineering Co., Chicago, Ill.*

Punch Press: Small 15-ton punch press is designed for fast, precision stamping. Solid one-piece, alloy steel crankshaft is heat treated and precision ground. Pin diameter is 2⅜ in. The flywheel, carried on two roller bearings, is 20 in. in diameter and weighs 200 lb, which is sufficient weight for full capacity punching at both high and low speeds. Long, V-type ramways provide precision guidance throughout most of the ram travel distance. Ram hole is 1 9/16 in. and accommodates standard die sets. Ram area is 4 x 5 in.; distance from center of ram to back of press is 6 in.; bolster plate area is 11 x 14 in. *Kenco Mfg. Co., Los Angeles, Calif.*

Wire Straightening and Cutting Machines: Model No. 2-C3 straightens and cuts wire from 1/16 to 3/16-in. diameter; No. 2-C4 is for 3/32 to 1/4-in. wire. Both machines have very rigid straightener-arbor support brackets to minimize vibration, completely enclosed straightener-arbor guard to protect machine and V-belts from oil, and heavy section V-belts with large pulleys. High-speed, five-die straightener arbor is mounted on ball bearings. Electric control buttons are flush mounted. A solenoid-operated trip mechanism is available and is recommended for small-diameter wire sizes. *Lewis Machine Co., Cleveland, O.*

Face Grinder: Horizontal work spindle on No. 11 face grinder permits wide variation of work-holding devices. Rotation of work in a vertical plane facilitates cleaning of the work-holding surface. Grinding with the periphery of the wheel, the machine produces accurate flat surfaces on work up to 10 in. in diameter and 3 in. thick on a permanent magnet chuck. Concave or convex surfaces up to 10 deg are also ground accurately. Wheel truing is obtained by the set-diamond method. Wheel slide grinding, work feed and truing speeds are quickly selected and set, and a dial indicates rate in use at all times. Automatic work feed can be set for inside and outside reversal or inside reversal only. Dwells from 0 to 2½ seconds are independently variable at the inside or out-



De Laval IMO rotary pumps can be furnished for almost any fluid handling problem in capacities to 750 gpm and pressures to 1,500 psig.

What to Look for in a Rotary Screw Type Pump

By W. J. Moncon, *Assistant Chief Engineer*
De Laval Steam Turbine Company

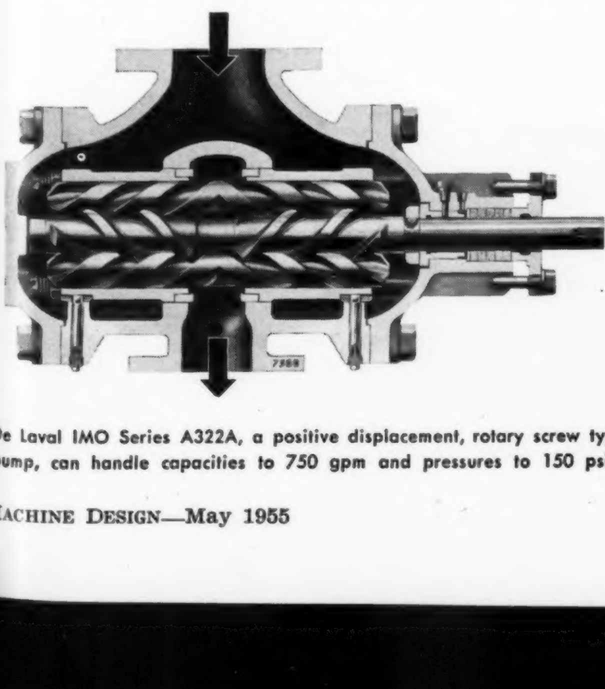
A sound knowledge of design, and how it affects performance, is the best insurance a buyer can have that he will get the pump he needs. This brief analysis of the IMO, a rotary three-screw pump manufactured by the De Laval Steam Turbine Company, will give you some of the necessary facts.

What qualities should you look for in a rotary type pump? It must, of course, meet specified capacities and pressures. But, it must also be efficient, operate quietly, stay on the job.

The axial flow of a screw type pump, and the resulting low inlet losses for any given pump speed, are important benefits that should be considered in making pump selections. The absence of timing gears and other mechanical features of construction also enable the De Laval IMO pump to operate at direct-connected motor and turbine speeds . . . to handle viscous liquids and high suction lifts.

One of the most important features of the IMO pump is the hydraulic turning of the idler or sealing rotors. The central or power rotor is the pumping element; the liquid pumped turns the sealing rotors.

A screw type pump is well suited for applications where pulsation-free flow is desirable. The axial flow of the liquid without trapping and the unique thread form which keeps closures fluid-tight contribute to quiet operation of the IMO pump.



De Laval IMO Series A322A, a positive displacement, rotary screw type pump, can handle capacities to 750 gpm and pressures to 150 psig.

Catalog LS gives useful application and specification data on the IMO pump. An article titled, *Rotary Pumps, Basic Considerations in Their Application*, contains a description of rotary pumps in general. For these publications, write on your company letterhead to De Laval Steam Turbine Company, 858 Nottingham Way, Trenton 2, New Jersey. DL-301

side or both. A positive stop is provided for both manual and power feed of the work head. *Brown & Sharpe Mfg. Co., Providence, R. I.*

Assembly Machine: Operations such as drilling, tapping, screw inserting, peening, pressing and crimping are performed without rehandling of the assembly or subassembly by the Aidling 100 mechanized assembly machine. Degree of automaticity, as well as output rate, depends on requirements. *Aidlings Inc., Brooklyn, N. Y.*

Testing and Inspection

Torsion Tester: Double Torsion testing machine loads and indicates torque in both directions of rotation, eliminating the necessity of taking down a specimen and readjusting grips to determine the full range of twist and pressure. It loads and reverses continuously with only one set of grips, twisting the specimen alternately in both directions until it fractures or until the machine is stopped. Electronic Selectorange indicating system is coupled directly to the double weighing system, and a light on the control panel indicates load direction. Tester has a full dial scale, in both clockwise and counterclockwise rotation, for each of three capacity ranges of 0 to 200,000 lb-in., 0 to 100,000 lb-in. and 0 to 20,000 lb-in. *Tinius Olsen Testing Machine Co., Willow Grove, Pa.*

Metals Tester: Echoscope works on ultrasonic impulse-echo principle to detect small internal defects in metal, to measure thickness of objects where only one side is accessible, and to estimate any local variations due to factors such as grain structure, recrystallization or porosity. A single head serves both as sender and receiver, and impulses are indicated on an oscilloscope tube. Device scans metal objects up to 16 ft thick for serious or minor defects. Portable instrument operates on 110-v power. *Curtiss-Wright Corp., Wood-Ridge, N. J.*

Friction Materials Tester: Design of machine for friction testing of materials, such as brake linings, under load is based on the fact that a loaded sample of material held and made to ride on the rim of a revolving drum, at a point on the vertical center line, results in a horizontal friction force tangent to the drum surface. A variable-speed, constant-torque power unit drives the drum through all speeds and loading conditions. Drum is on the end of a shaft that is mounted in self-aligning ball bearings. Maximum shaft speed is about 900 rpm. A restraining device maintains position of test sample on the vertical center line of the drum regardless of any variation of frictional force. This pressure-sensitive device continously records characteristics of material under test. Samples under test can be loaded in 25-lb increments up to 200 lb. Electric heating elements which can raise drum temperature above critical temperature of most friction materials are located in a housing which surrounds the drum. Minimum air pressure required is 50 lb, and the machine can be adapted for 220 or 440 v ac. *Link Engineering Co., Detroit, Mich.*